MAGELLAN PROJECT

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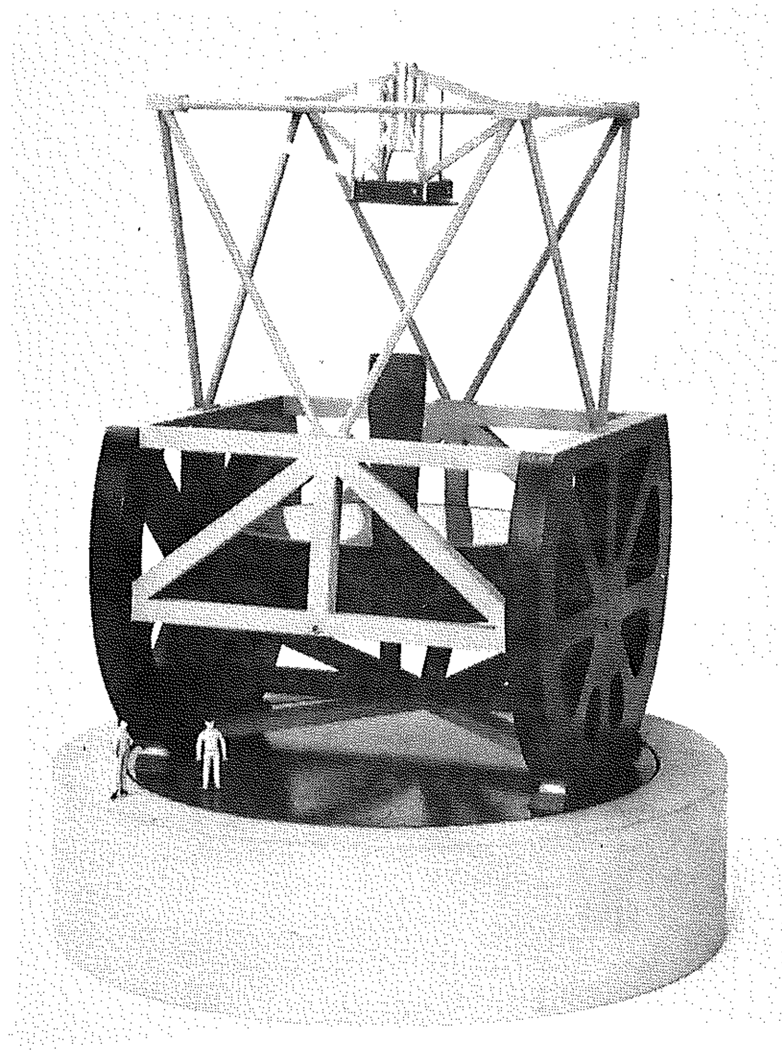

Summary Report
Octagonal and Dome Enclosures

L & F Industries
Huntington Park, California
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I. COST, SUMMARY AND COMPARISONS

A. GENERAL BACKGROUND AND DISCUSSION

Three different enclosure concepts have been studied by L & F Industries for the Magellan 8m Telescope: rectangular, octagonal and hemispherical. The most recent work has been done on the octagonal and hemispherical versions and they are not only properly sized for the current f1.2 telescope design but also properly interfaced with the current facility arrangement. The rectangular design was sized for an f1.0 telescope design and arranged for a different facility layout, and therefore may not provide a valid comparison but is included to provide additional background information.

The structural details of the octagonal and hemispherical enclosures are included as Sections II and III of this report and detailed information on the rectangular structure can be found in the L & F Industries enclosure report dated March,1987. Drawing E271100 sheet 1 showing the general size and arrangement of the rectangular enclosure is included in the appendix of this report for reference and drawings of the octagonal and hemispherical enclosures are included in Sections II and III herein.

This report is intended to be a summary of the enclosure work done to date and a comparison of the cost, technical features, and advantages/disadvantages of each type. In trying to pull the loose ends of these various studies together to make meaningful comparisons, the following difficulties were encountered:

1. Octagonal Enclosure

a. Original Octagonal Concept

The original octagonal enclosure concept was conceived in the spirit of "brainstorming" to address cost drivers in an effort to reduce costs. In this spirit the following concepts were suggested:

* An octagonal structure making use of flat panels and yet minimizing surface area.

* The use of honeycomb skin panels to provide adequate stiffness to carry imposed wind, snow and ice loading with minimal supporting structure.

* The use of rectangular or square tubing for structural members to simplify intersecting connections.

* Using a "field construction" technique to minimize shop labor, bolted connections and shipping costs.

* The possible use of the "ball bearing" support as opposed to conventional trucks.

The structural analysis done to date and summarized in Section II is based on the above concepts.

b. Modified Octagonal Concept

Subsequent discussions primarily aimed at reducing the risk of field construction and of the use of honeycomb panels have resulted in the following suggested modifications to be incorporated into further analysis:

* Use of some commercially available roofing system in place of the honeycomb panel. This change will require the addition of intermediate structure to support the long spans required between main structural members.

* Bolted connections incorporated into the main structure to allow for shop assembly and test.

* The possible use of rolled sections instead of square tubing.

c. Octagonal Pricing Caviats

The pricing study previously submitted incorporates these suggestions in a budgetary sense, however since the analysis and the pricing are now not synchronized, the pricing could be refined by a more detailed structural analysis.

The pricing previously submitted for the octagonal has been further modified in the tables that follow to cover the costs of an inner insulated skin and a windscreen in order to be comparable to the hemispherical requirements.

2. Hemispherical Enclosure

The hemispherical enclosure pricing may be the best benchmark given in this report since the analysis and the costing are all in line with current thinking regarding shop assembly, construction techniques and insulation.

The construction techniques are the same for the IRTF dome except that the shutter will be bi-parting and there will be an inner insulated skin panel. Labor hours for construction are also extrapolated from the IRTF project, which combined with current material prices using weights derived from current analysis should yield reasonably accurate pricing.

3. Rectangular Enclosure

The rectangular enclosure priced in March of 1987 differed significantly from current conceptual requirements in the following areas:

* The enclosure was 78-1/2 feet square on the outside and designed to clear the f1.0 telescope design.

* The overall height above the rail was 69-1/2 feet which allowed for the shutter opening to clear the beam path down to 15° above horizon as well as allow for a bridge crane overhead.

* The enclosure included a co-rotating floor.

* Additionally the prior pricing included the following items which have been deleted from the price comparisons that follow:

  a. Concrete for pier
  b. 5 Ton bridge crane
  c. Louvre system
  d. Equipment lift
  e. Exterior mirror lift
  f. Control room
  g. Building electrics (partial)
  h. Plumbing
  i. Air conditioning
  j. Air duct
  k. General Contractors fee

The accuracy of the resulting price is somewhat suspect in that the enclosure is basically the wrong size and the structure is sized for inapplicable crane loads as well as including the co-rotating floor. Also, to be kept in mind, the 1987 prices should probably be increased about 8% to be current.

B. CRITERIA FOR COMPARISON

The following categories have emerged as criteria for comparisons between enclosure types:

1. Cost

Cost comparisons should include not only engineering and manufacturing cost but also shipping and field erection costs.

The costs for engineering and manufacturing are presented herein and the following comments are offered regarding shipping and erection.

* Shipping

Shipping costs will be proportional to volume and weight.

There are no particularly insurmountable difficulties with any of the enclosures.

The octogonal may well be the least expensive to ship as it will package efficiently and weight is modest.

* Field Erection

Field erection costs are proportional to weight and complexity. Many of the cost drivers apply equally to all enclosure types such as insulation methods and sealing methods.

The same types of skills are required for erecting both the octagonal and hemispherical enclosures. The irregular geometry of the hemisphere may increase cost slightly above the octagonal, whereas, the weight and surface area of the rectangular may outweight the simplified geometry. The octagonal enclosure must marginally rate best for field erection.

2. Weight

Weight is important both for raw material cost, thermodynamics performance, air conditioning costs (if applicable) shipping and erection costs.

The octagonal enclosure here again is the marginal leader with the hemispherical enclosure running a close second.

3. Surface Area

Surface area impacts requirements for wind, ice and snow loading as well as thermal control.

The hemisphere wins here with the Octagonal a close second.

4. Other Criteria

Other criteria such as sealing methods, insulation methods and ventilation apply more or less equally to all types of enclosures.

C. SUMMARY

1. Summary Table

With the risk of publishing a table which may be subject to interpretation without due regard to some of the prior discussion, the following table summarizes the important criteria as studied thus far:

	Rectangular	Octagonal	Hemispherica
Weight (lbs)	900,000	310,000	340,000
Surface Area (sq ft)	27,500	13,700	12,200
Inside Clearance Radius (ft)	36	42	42
Cost (Fob: Los Angeles)	3,606,000	2,877,000	2,934,000

2. Cost Backup Information

a. Rectangular Enclosure

Price quoted in 1987		$4,723,850
Less	concrete pier	265,000
	5 ton crane	50,000
	Louvre Assemblies	150,000
	Equipment Lift	30,000
	Mirror Lift	150,000
	Control Room	24,000
	Electrical 150k total	100,000
	Plumbing	5,000
	Air Conditioning	50,000
	Air Duct	36,000
	General Contractor Fee	524,850
	Net	$3,339,000
Add 8% 1987-1989		267,000
	Total	$3,606,000

For reference see price summary excerpted from the 3/87 report on the following page.

FROM 3/87 REPORT - RECTANGULAR ENCLOSURE

C.I.W. ENCLOSURE SUMMARY

Structural Steel	$ 1,006,000.
Siding (insulated, inner & outer)	570,000.
Concrete (530 cy @ $500/cy)	265,000.
Ring Beam & Rails	304,000.
Trucks, Drives, Idlers	284,000.
Windscreen	65,000.
5 Ton Bridge Crane	50,000.
Shutter Drives	125,000.
Louver Assemblies	150,000.
Skirt, Seals, Misc.	170,000.
Equipment Lift	30,000.
Exterior Mirror Lift	150,000.
Control Room	24,000.
Building Electrics	150,000.
Plumbing & Fixtures	5,000.
Air Conditioning (20T @ 1000/T + 50T @ 500/T)	50,000.
Air Duct (8 ft dia x 200 ft long)	36,000.
Containerize & Ship to Dock	65,000.
TOTAL	$ 3,499,000.
General Contractor Fee (15%)	524,850.
TOTAL	$ 4,023,850.
Trial Assembly (steelwork & drives)	250,000.
Engineering	
Arch, Structure, Mechanical, Electrical	250,000.
Mechanical for Drives, Crane, Lifts, Seals, etc.	200,000.
	$ 4,723,850.

b. <u>Octagonal Enclosure</u>

Structural Steel Fabrication 215,000 X $5.00 lb....................	$1,075,000
Skin Panels (Robertson SR3) 15,000 sq ft X $12.00..................	180,000
Flashing and Trim......................	100,000
Inner lining 12,000 X 1.5 X $9.00..................	162,000
Shutter Drives.........................	80,000
Rail 300 ft X 150/ft...................	45,000
Windscreen and Drives..................	90,000
Jib Crane, 5 Ton.......................	25,000
Electrical - Power and Lighting........	50,000
Assembly 5000 hrs X $50.00.............	250,000
Disassembly, Crating...................	100,000
Engineering 6000 hrs X $70.00..........	420,000
Contingency 10%........................	300,000
TOTAL.........	$2,877,000

c. Hemispherical Enclosure

Raw Materials including:

3/16 skin
structural ribs
arch and ring beams
shutters
miscellaneous structure
trucks and rail

Total Raw Materials	$	254,000

Purchased Components and Services:

sheet metal skirts, seals
drive components - motors, gearboxes, bearings & etc.
hardware - bolts, paint, misc. electrical

Total Purchases	$	300,000
Labor		
Engineering 7000 hrs X $60.00	$	420,000
Shop 30,000 hrs X $45.00		1,350,000
Total Labor		$1,770,000
Windscreen (per rectangular study)	$	65,000
Insulation - Outer Sprayed @$3.00 sq ft X 15,000	$	45,000
Insulation - Inner Panels @$10.00 sq ft X 15,000		150,000
Total Insulation	$	195,000
Packing and Ship to Dock, L.A.	$	50,000
Contingency	$	300,000
TOTAL		$2,934,000

MAGELLAN PROJECT - OCTAGONAL ENCLOSURE

INTRODUCTION

At the time that this preliminary design work was begun, a new and rather specific goal was established for the enclosure: to apply a more conceptual design approach in an effort to minimize both weight and cost of the enclosure system. The premise upon which this concept is based follows:

Two extremes (in terms of geometry and weight) in large telescope enclosures exist presently. The "Box" enclosure (such as was used by M.M.T. and A.R.C.) provides the simplest geometry to manufacture. However, this concept also has the largest surface area due to the excess material in the corners far from the clearance radius of the telescope. Compounding the large surface area is the fact that there are so few surfaces, that each surface is very large. Under wind and snow loading, this means very large bending moments that must be reacted by the structure; large surface area and large bending sections result in high weight.

Conversely, the conventional hemispherical dome (hereinafter referred to as "Dome") clears the telescope at all points by the same constant, minimum clearance dimension. This concept then has the minimum surface area (at least in the case of a non corotating enclosure), but at the same time its geometry is more complex from the manufacturing standpoint.

The Octagonal Enclosure concept is the result of an attempt to optimize between these two extremes. It has nearly as low a surface area as the Dome and relatively small, flat panels for reduced bending moments and ease of manufacture. This concept design is shown on drawings E271036 shts. 1-3, E271037, E271038, and E271040.

As shown on E271036, this geometry consists of a right octagonal cylinder from the ring beam up (to a level about 16′ above the ring beam), then a transition from the octagon to a square at the top of the enclosure. In this design, the side or elevation views of the rotating structure, when taken along the global coordinate axes of the structure, represent one-half of the same octagon that is seen in the plan view. This effects seven common rectangular panels in the (octagonal) cylindrical area, and 3 common large rectangles and 4 common triangles in the transition area. The bi-parting shutters then complete the geometry (in their closed position).

This design is 93′- 0" in outside diameter, with a minimum inside clearance radius of 42′. This provides a minimum clearance of 3′

to the telescope at its closest approach; that is, when a corner of the square head-frame of the telescope is positioned at the center area of the flat rectangular panels.

Actually, the technical name for this shape (as a geodesic dome) is "Rhombicuboctahedron". In the interest of sanity, however, it will be herinafter referred to as "Octagonal Enclosure". It should be noted that in early preliminary work it was called "Hybrid" Enclosure, since it can be seen as a combination of the box enclosure and dome enclosure.

Features and benefits of the Octagonal Enclosure are defined somewhat throughout the report. Summarizing briefly, though, it is thought to have low weight and simple geometry, effecting low cost and good thermal performance.

Some information in this Octagonal Enclosure section is common also to the later Dome Enclosure section of the report, and these areas have been noted as such in the Dome section.

STRUCTURAL DESIGN:

The structural design consists of an all-steel spaceframe fabricated from structural tubing. The structural tubing provides the benefits of 1.) High column strength for axial compression components of load reaction, 2.) Reasonably good bending strength and stiffness, 3.) Ease of manufacture (particularly using the field-welding technique described later), and 4.) Nearly free ventilation of the entire spaceframe structure, effectively removing nearly all of its thermal mass from the inside of the enclosure, to be exhausted downwind from the system, with the "telescope mass" ventilation air.

The panelling system used is one in which a standard, developed, commercial product is customized for this application; honeycomb sandwich panels. The panel is a precision bonded panel with 22 ga. steel (.030 in. thick) skins separated by a 3" thick structural paper honeycomb core, foam-filled for thermal insulation (to reduce air conditioning costs during the day). The insulation value for this panel is approximately U .06 ("R17").

The edges and ends of this panel would be lined with bonded, precision extrusions with a tongue-and-groove configuration on the edges. This will allow for caulking of the edge joints at installation. The exact configuration and caulking method require customizing for this application to preclude leakage at the joints. However, it is intended that a configuration similar to that on commercially-proven preinsulated panels, (such as Inryco panels), be used. These (honeycomb sandwich) panels are used successfully in similar applications in which they must be weather-tight.

The benefits of this type of panel are significant. It has very high strength, minimizing the number of "girts" required to support the 46 psf (nominal) pressure load at the survival wind load of 150 mph. It is also light in weight and preinsulated, eliminating the need for a double panelling/insulation system with an air gap and/or ventilation in between. Although the cost of these panels is considerable (about $20/ft2), it may be lower than the total cost of a more complex panelling system.

Details of this construction are shown on E271036 sht. 3, and elaborated upon in the section "Construction Plan".

THERMAL CONTROL:

This structural design lends itself to an effective and inexpensive thermal control system for the enclosure structure. A ventilation system is existing as part of the thermal control system for the telescope structure. The same system can be used to pull air through all structural members in the enclosure structure.

The system can use a two-fold method:

1.) During the daytime the telescope and enclosure structures are isolated from outside air (by remote closing of one large air valve in the ducting system between the structures and the exhaust blower downstream of the valve). The dome is air conditioned to maintain the best-guess starting nighttime ambient air temperature. Since both the telescope and the structural tubing of the enclosure are inside the insulation, they will be at or very near the starting nighttime temperature, when the air conditioning is shut down and shutters open to begin observing.

2.) At this time the air valve is open and exhaust blower turned on. One ducting path from the valve leads to the telescope structure which has ventilation holes at its very top end and strategically placed throughout the structure. A second duct from the valve leads to the skirt area of the enclosure. This skirt area has a crude (canvas or other?) seal between its rotating side and stationary side to somewhat isolate it from the outside air. There is also a moat seal between the rotating ring beam and the top of the stationary building, but still inside the skirt area. The skirt then acts as a plenum connected to which are one or more holes in the rotating ring beam. The ring beam then has eight ventilation holes cut in its top side connecting it to each of the eight columns in the structure. Like the telescope, the structure then has (mostly internal) holes such that air flow begins at the very top end of the enclosure structure, then feeds downward through all members to the ring beam, then skirt, then exhaust duct to be discarded downwind with the telescope air. It should be noted here that, if the crude skirt seal allows significant leakage, an additional valve would be required between the rotating ring beam and skirt plenum, to reduce daytime transfer between the enclosure and outside, thus minimizing the daytime air conditioning costs.

As the night ambient air temperature falls the heat from the telescope structure and enclosure structure exhausts downwind from the observatory, having very little detrimental effect on seeing. The only significant mass left in the enclosure is that of the 22 ga. steel skin on the inside of the preinsulated panels. This .030 in. thick steel skin of course has a very low time constant and minimal effect on seeing.

SHUTTERS:

The bi-parting shutters are shown on drawing E271037. They are also fabricated predominantly from structural tubing with the same type of honeycomb composite panelling system. Drawing E271037 is not quite current in that a windscreen design has been incorporated with the shutters, described later in this report. Shutter drives are TBD, but will probably consist of rack and pinion drives at the upper and lower end of each shutter.

Another type of shutter was investigated as part of this effort. This concept consisted of a series of 6 large hinged doors, one each along each of the flat edges on the two sides of the slit. It was found that linear actuators were not feasible due to the large rotation angle (nearly 225 degrees) and the way in which the moment on the doors varied with rotation angle. Very large planetary reducer rotary actuators (electric motor driven) are a possibility to open and close the doors under gravity loading. However, the moment on the doors is much greater due to wind loading (they actually try to open up under a side wind on the enclosure). It was found not feasible to react this moment with the actuators. In principle, lock-pin mechanisms could be used to react the large wind moments, but it was finally concluded that this approach entailed unnecessary complication, impacting cost and reliability.

WINDSCREEN:

A windscreen concept design has been developed specifically for this Octagonal Enclosure, and is summarized in a later section of this report.

ENCLOSURE ROTATION BEARING AND DRIVE:

Considerable preliminary design was done developing the concept of a large diameter, inexpensive ball bearing which could be applicable to either the Octagonal or Dome enclosures. This bearing is shown on drawing E271036 sheet 2. It consists of relatively crudely made, moderately hard races, grooved on the bottom side only. Radial definition of the rotating enclosure would be accomplished by the separate track rollers shown.

In this way, the dimensional accuracy of the grooved race is not at all critical; its out-of-roundness simply adds slightly to friction to be overcome by the rotation drive. This design lends itself to the use of an oil moat seal as shown. This would serve both to lubricate the bearing and form a perfect (airtight) seal with virtually no friction (that is, friction due to the seal).

A number of potential design problems were addressed in doing this work, which are addressed in later sections "Pressure Drop Across Oil Moat Seal" and "Bearing Test".

The initial motivation for using this design was that it might be much cheaper than using conventional trucks. However, when the "Truck Alternative" was subsequently done, it was found that trucks may also be fairly inexpensive for this lightweight system. However, one significant advantage does remain. The ball bearing design has a very shallow vertical dimension between the top of the stationary building and the bottom of the rotating building. This readily lends itself to the oil moat seal, which could effect much lower air conditioning load during the entire lifetime of this observatory. It is also possible that this design could be very quiet due to the low contact stresses (ref "Bearing Test") and the fact that the contact points are fully lubricated.

Detail work was not done on the enclosure rotation drive. However, the anticipated concept includes one or two friction drives, electric motor driven (through a gear reducer as required) similar to that depicted on E271036 sht. 2. The drive wheel would use an elastomeric traction surface for high friction and quiet operation. A proven, rugged, drive wheel such as those used on fork lifts has been suggested and is considered appropriate.

TRUCK ALTERNATIVE:

The truck alternative for the rotation bearing is shown on drawing E271038. This concept is similar to that used previously in the Box Enclosure concept design, but scaled down for this much lighter load and flipped "upside down". This system uses eight truck assemblies, one each on top of a column in the stationary building.

The two wheels are mounted using a "structural" bogie. The bogie is mounted rigidly to the stationary building for three degrees of freedom: X and Y translation (horizontal in-plane translation), and rotation about a vertical axis. The remaining two rotations, and vertical translation, are defined through the combined spring rate of the flexure plate and Fabreeka pad springs as shown.

In this way, equal load sharing between the two wheels on each bogie, as well as between the eight bogies, is assured. It is felt that this system may be especially quiet (as compared to many other truck systems), since the direct load path between the rotating enclosure and stationary building is through the (high dampening) Fabreeka pads.

As shown on the separate "Truck Alternative - Weight As Compared With Ball Bearing", it is estimated that the total system weight is about 16,000 lbs. heavier using the truck design.

MAGELLAN PROJECT - OCTAGONAL ENCLOSURE

CONSTRUCTION PLAN

The concept presented herein employs extensive use of structural tubing. This then requires construction techniques not used in either a hemispherical dome nor a box-type enclosure using "steel building" techniques.

The enclosure structure is shown on drawings E271036 (shts. 1 thru 3), and E271037 (Bi-Parting Shutters). Unless otherwise noted, all views are referenced from drawing E271036 sheet 3.

This plan entails fabricating individual structural members to the maximum extent possible in the shop, welding these members into large (virtually flat) panels on site, then erecting these relatively few panels into place and making the minimum number of welds possible during erection. To save cost, bolted joints have generally not been used; however any welded joint can be replaced with a somewhat more costly bolted joint.

The structure lends itself to on-site welding, since nearly all welds are small; that is, between members with 1/4" wall thicknesses. The only significant exception to this are the (total of 16) joints in the TS 20 x 12 x 1/2"; still not really heavy welding. Thus, not only are the welds easy to make on-site, they will have low residual weld stresses due to the long slender design of the individual members.

It is assumed that a large flat paved or cemented area will be available - about 100′ x 100′ would be nice. This could be where the adjacent office building and parking area will later be constructed, for example. In lieu of this, the enclosure slab itself could be used to pre-fabricate the panels which could then be set aside (out of the way) for later erection. It is also assumed that the footings with anchor bolts (8 column footings and 2 brace footings) already exist as of the beginning of the step-by-step construction procedure as follows:

STATIONARY BUILDING:

1. Four panels will first be fabricated as shown in view A. The two columns in each panel will have the top and bottom flange plates shop-welded; the top flange plate is machined perpendicular to the axis of the column so that, once erected and leveled, the 8 pads will define a rather flat and level plane for the stationary ring beam. The top and bottom TS 12x12x1/4 chords are shop saw-cut with lengths held plus/minus 1/8". Likewise, the diagonal is shop saw-cut. With the diagonal set back slightly from each corner, adjustment exists so that the diagonal will fit

properly, with room for an all-around weld. A typical corner weld for the 1/4" wall structural tubes is shown in view C. The columns are specially fabricated as shown in view B. The W12x19 girts are cut to length (square-cut end) on-site so that they are properly located to accept the preinsulated panel joint. Note that the preinsulated panels can even be installed on each of the four panels prior to erection (while flat on the paved work surface). Two of the panels will have special fittings shop-welded near the top of one column each to later accept the two ground braces shown on E271036 sht. 1.

2.) The four panels are erected into place (they are the "corner panels" rather than back or side panels). They are blocked off the footings about two inches, with the 8 top flange plates held level by transit. They are braced temporarily to ground, and grouted in place at the bottom end of the 8 columns.

3.) The (two side and one back) bracing sets between the four panels, as well as the two permanent ground braces are then site-fitted (saw-cut to site-measured dimensions) in place and welded. These seven "panels" now appear identical, except that the back panel requires framing for the two large "barn doors" as shown on E271036 sht. 1 view A-A. (These are access doors to allow bringing in or taking out anything that can fit in the area between the outside diameter of the telescope pier and the inside diameter of the stationary building; instruments, etc.)

4.) The stationary ring beam is now constructed either in place on the top of the eight columns, or on the ground work-area for later carrying into place with a large crane. (The crane would necessarily be "inside" the ring beam as it carries it into place). Each section of the stationary ring beam is shop formed to the correct radius, with ends machined and guide tabs welded in place as shown in view E. The sections are pulled together with turnbuckles temporarily welded to adjacent ring beam sections. The stationary ring beam is positioned radially at each column so that it is round within plus/minus 1/8" (or whatever tolerance can reasonably be held under these conditions). It is then welded to the top column flange plates as shown in view D.

5.) The oil moat channel and lower bearing race support are now welded in place. (Ref E271036 sht. 2). The channel is shop-rolled to the correct radius. Of course, the channel is segmented (made in lengths of approximately 20 feet). At each joint between channel segments, a seal weld is made and the system checked to confirm that it holds liquid without leaking. The lower bearing race support is also shop machined and rolled but is flexible enough to adjust its radius at installation. It is then held a fixed dimension off the inside or outside radiused surface of the stationary ring beam and welded in place.

The stationary building structure is now complete.

ROTATING BUILDING:

1.) The rotating building is now constructed according to the plan shown in view K. The ring beam is first constructed either in place blocked off the stationary ring beam or in the paved work area and walked into place with two cranes, or some combination thereof.

2.) The second step is to site-fabricate the arch as shown in view F. The arch consists of 5 members (TS20x12x5/16) whose ends have been accurately shop-prepared (either machined or saw-cut accurately). The four joints in each arch are made while flat on the paved work area by simply welding both sides of the joint to a 20 x 12 x 3/4" plate. After welding a temporary brace between the arch bottom ends, the arch is erected into place with one or two cranes, welded to the rotating ring beam as shown in views F and G, and temporarily braced laterally to the ring beam.

3.) Ditto the second arch, as shown in view K.

4.) The arch back back cross-member is now welded in place, as shown in view K.

5.) Next the side panels are fabricated in the paved work area (see view K item 5 for definition). Actually, this "panel" consists of two panels which are each fabricated flat, then joined into one panel still in the paved work area. Panel 5 is then erected and welded two places to the ring beam and two places to the arch.

6.) Ditto panel 6, view K.

7.) The corner members are now filled in by site-measuring and saw-cutting each individual member to fit.

8.) Ditto the back panels between arches, and shutter support beams.

9.) The preinsulated panels are now installed. This involves heavily caulking the panel edges, positioning each panel longitudinally, then engaging laterally with the adjacent panel, and joining at the ends as shown in views L and M. It is intended that a tongue-and-groove joint (depicted crudely in view M) will be designed in the detail design phase which will seal effectively, as do similar joints in commercially-available foam core panels existing on the market. Flashing is installed also at this time.

10.) The rotating building structure is now complete. The bearing upper race is installed (bolted through the inside of the rotating ring beam using access holes in the inside surface of the ring beam). The bearing balls are installed, the rotating building is jacked off the blocks and then lowered onto the bearing.

11.) Finally, the shutters are installed (after being fabricated in the adjacent work area), as well as drives, slip rings, skirt, ventilation louvers, etc. (ref E271037 and E271036 sht. 2). Additionally, all structural members' surfaces can be thermally insulated (spray foam or structural panels applied with adhesive). In this way, (in combination with suction ventilation of the entire structure) virtually all thermal mass can be removed from the inside of the enclosure system.

OCTAGONAL ENCLOSURE WINDSCREEN

The earlier box enclosure concept design consisted of a rotating observing floor (ref drawing E271100 - "8 Meter Telescope Enclosure" report dated March 1987). In that concept it was possible to have a slot near the front of the observing floor through which the windscreen could pass and thus be stored (in a single large drape) below the observing floor. The windscreen, in the stored position, then swept out an annular area near the perimeter of the stationary building for which clearance was provided.

The current enclosure concept (either octagonal or hemispherical type) employs a stationary observing floor only 16 feet below the altitude axis of the telescope. Since one cannot "slot" the stationary floor, windscreen storage must be accomplished above the observing floor.

There is insufficient room to store a draped, rolled, or bellows type of windscreen above the observing floor (within the 16' dimension) and clear the telescope adequately.

One solution in the case of the octagonal enclosure (and possibly also the hemispherical enclosure) is to have a 4-part rigid panel type of windscreen which would store immediately inside of the bi-parting shutter inside surface (ref drawing E271040). This would employ two lower sections (one in each shutter) and two upper sections (also one in each shutter). The windscreen effect would then be available in two increments: Top of windscreen 18 feet above the altitude axis, and top of windscreen 31 feet above the altitude axis (see drawing).

Each of the four rigid panels would be supported by telescoping tracks: The rigid panel would run on wheels in the telescoping track and the telescoping track on wheels in a track which is mounted integral to the shutter. The panels could be aluminum honeycomb composites with a horizontal structural member along the top and bottom edges.

Only preliminary analysis has been performed on this concept to date, but based on this analysis, this concept is thought to be feasible.

A similar concept can be used in the hemispherical design, but of course would require curved windscreen panel sections.

WEIGHT SUMMARY

MAGELLAN PROJECT OCTAGONAL ENCLOSURE

DESCRIPTION	WEIGHT
Rotating Building Bare Structure, FEA	104,500
" " Shutter Supports	7,400
" " Shutter Structure (2)	30,780
" " Girts (W12x19)	3,400
Rotating Building Structural Steel	146,000
Rotating Building Preinsulated Panels	65,000
Rotating Building Miscellaneous (drives, skirt, windscreen, etc.)	15,000
TOTAL WEIGHT ROTATING BUILDING ASSY	226,000 lbs.
Stationary Building Bare Structure, FEA	76,500
" " Girts	4,800
Stationary Building Structural Steel	81,300
Stationary Building Preinsulated Panels	27,700
Stationary Building Miscellaneous (drives, bearing, etc.)	5,000
TOTAL WEIGHT STATIONARY BUILDING	114,000 lbs.

****

TOTAL WEIGHT OCTAGONAL ENCLOSURE SYSTEM 340,000 lbs.

$$T = \frac{226{,}000}{2(\pi)(42 \times 12)^2(.2833)} = 0.500 \text{ in.}$$

PRESSURE DROP ACROSS OIL MOAT SEAL

It is assumed that any rotating enclosure seal other than the subject moat seal will have relatively large air leakage and thus incur a substantial increase in daytime air conditioning costs. This in combination with free bearing lubrication mean that there are strong advantages to the oil moat seal concept.

The skirt surrounding the ring beams also encloses the bearing with its oil moat seal. The skirt has a rotating element (attached to the rotating building) as well as a stationary element, attached to the stationary building. A gap exists across the transition between the two skirt elements which is small as compared to the cross-sectional air flow area of the skirted area.

Therefore, the skirted area will act as a plenum with an inlet leak rate on the upwind (high external pressure) side and an exhaust leak rate on the downwind (low external pressure) side. If the leak rates (upwind vs. downwind) were identical, the static pressure inside the skirt would split the difference between the upwind and downwind external static pressures.

The static pressure inside the enclosure during a high wind will be due to a myriad of small leaks around its 25,000 square feet of surface area leaking to or from the outside air static pressure. Therefore, one might conclude that the internal static pressure is approximately equal to the average of the external static pressure over the entire 25,000 square foot area.

The pressure distribution over a hemisphere on a cylinder (plan view) is shown below. By inspection, the average external pressure coefficient (averaged by surface area) is about -0.4 (of stagnation pressure). Also, the average downwind side static pressure over a substantial length of perimeter is about -0.4. Therefore, if one were to provide a crude seal (canvas or silicone rubber flap or felt, for example) around the skirt gap which would seal under positive external pressure and vent under negative external pressure, the skirt area static pressure should be very close to this -0.4 pressure coefficient.

Therefore, with the above skirt seal, and under the above assumptions the pressure differential across the oil moat seal would be very small. Even without the skirt seal, if one assumes that the skirt area static pressure splits the difference between the upwind and downwind external pressures, the pressure difference across the moat would be about 0.4 pressure coefficient, and the existing 2.75" deep oil moat would be good for a 136 mph wind before spilling oil.

The added crude skirt seal would also preclude nearly any dust and sand from getting into the skirt area, with gravity (acting on what dust and sand does get into the skirt area) and the fact that the oil moat has zero air flow across it, precluding any dust and sand getting into the oil moat.

Figure 11:19 Circular dome mounted on cylindrical base.

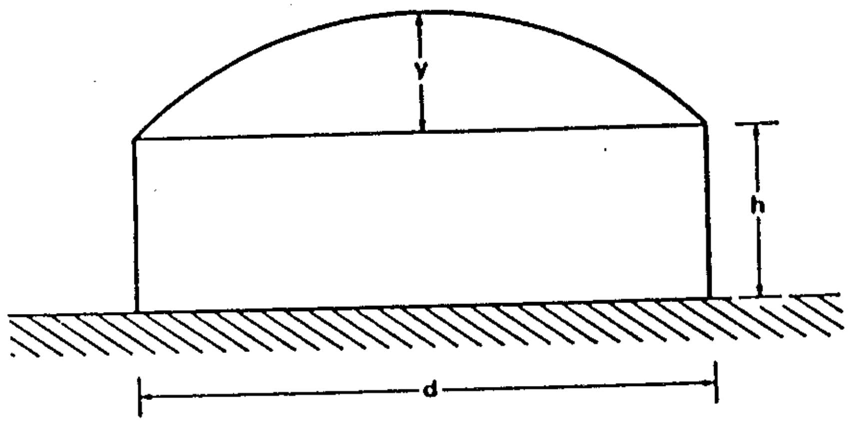


Figure 11:19a Elevation.

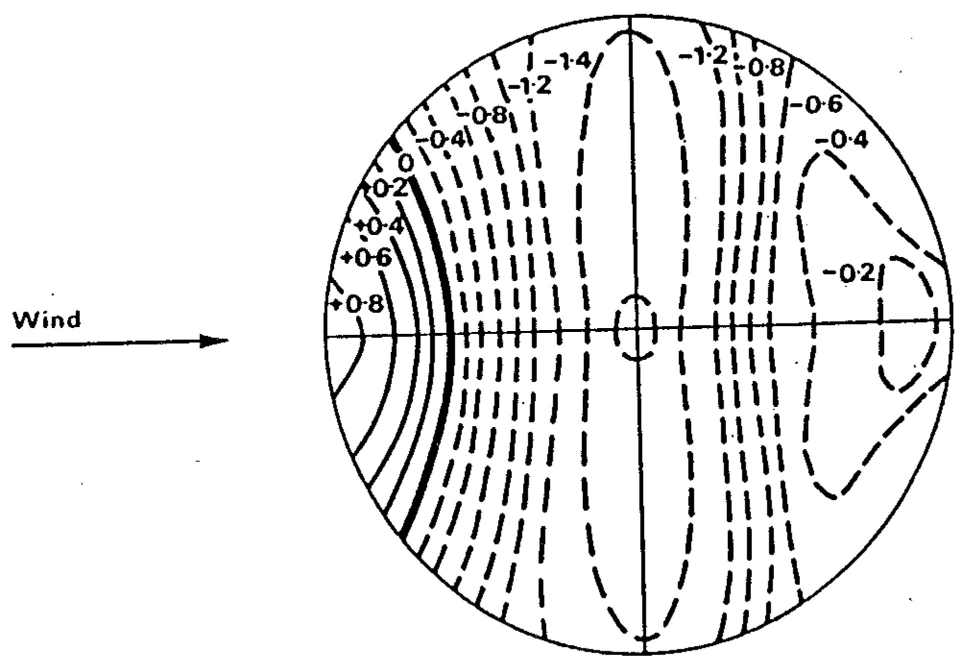


Figure 11:19b Plan view: pressure coefficients for $y/d = \frac{1}{2}$ (hemispherical dome) and $h/d = \frac{1}{2}$.

MAGELLAN PROJECT - OCTAGONAL ENCLOSURE

BEARING TEST

The proposed 92 ft. diameter ball bearing is rather unique in that it is very crude as compared with conventional ball bearings. For example:

1.) The races are somewhat softer.

2.) The races are not as precisely machined.

3.) The races are not continuous.

This bearing will have an average load per ball of about 100# per ball, with an estimated maximum of between 1,000# and 2,000# per ball. A conventional bearing of this ball size has a static load rating of about 25,000# per ball. It is felt that the very light loading on this bearing will allow it to work well and have good life even with the above listed disadvantages.

However, this could be verified with the following proposed bearing test:

A bearing could be made of about 120" in diameter. It would be made with a full size cross-section (races, balls, etc.) except that the "ring beams" would be made using 5 x 3 x 3/16" structural tubing (so that they can be roll formed to this much smaller diameter). The ring beams would be fabricated in the same manner as the full-sized bearing; that is, welded with no machining. The races would be made in the same way as for the 92 ft. diameter bearing; made from the same material, machined and segmented in the same way. The moat channel would be of slightly different dimensions, but would still accomplish the oil moat concept.

The above bearing would be assembled and loaded in such a way as to simulate local loading per ball of about twice that expected in the real bearing. It would be run under this load for an extended time to simulate an acceptable life for the bearing. For example, if the real enclosure sees 2 revolutions per day on average, then the test bearing running at 5 rpm would see about one year of real bearing life per one day of test operation.

When the main test is complete, (assuming no apparent malperformance has occurred as yet) the balls and races will be inspected for wear. At this point, the bearing could be reassembled and highly contaminated with dust and sand and operated for an additional period to see this effect.

TRUCK ALTERNATIVE

WEIGHT AS COMPARED WITH BALL BEARING

ITEM	WEIGHT CHANGE
Bearing	- 7,400
Rail (ASCE 40) incl. attach.	+ 4,500
Trucks (8 @ 1070#)	+ 8,600
Stationary Ring Beam	- 29,900
Guide Roller Assemblies	+ 3,600
Columns (TS 20 x 12 x 1/2)	+ 15,000
Top Chords (TS 14 x 14 x 5/16)	+ 5,200
Misc. - Truck Support Brackets, etc.	+ 6,400
Rotating Ring Beam	+ 7,200
Skirt	+ 2,400
	+ 16,000 lbs.

TRUCK DESIGN IS APPROXIMATELY 16,000 LBS HEAVIER

MAGELLAN PROJECT OCTAGONAL ENCLOSURE

FINITE ELEMENT ANALYSIS

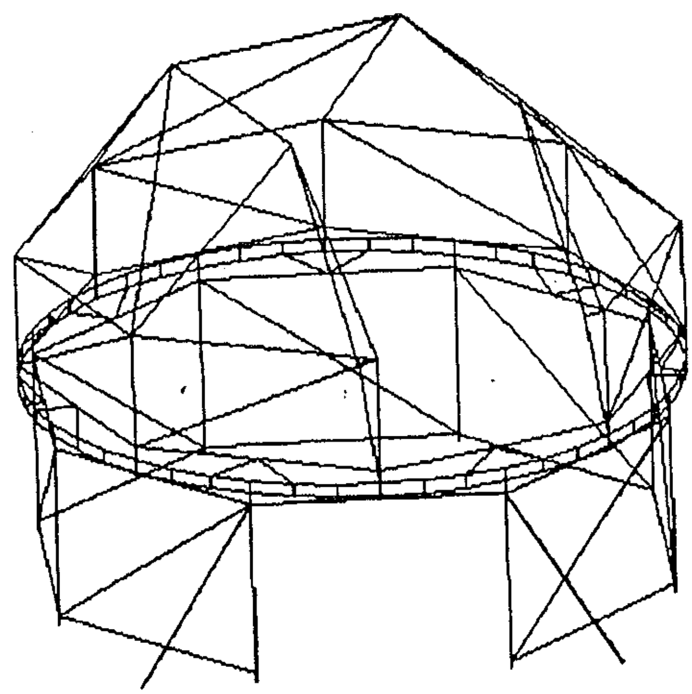
A concept design level, finite element type, structural analysis was performed to help size the structural members in this spaceframe type structure.

The model required was quite modest, in that there are relatively few actual elements in the real structure, and only one beam element was used in the model for each real member of the structure. Using this technique, local bending stress due to the pressure load distribution from the honeycomb panels was added to the results manually. In a detail design model, further meshing of the members would enable a more accurate determination of these bending stresses due to the distributed wind and snow loads.

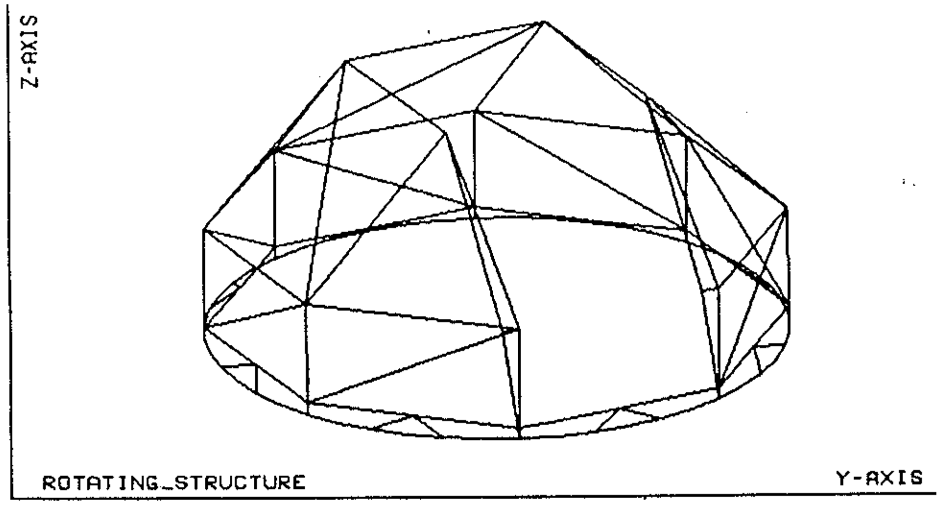
Two basic load cases were evaluated: 1.) Gravity acting on the structure plus 1" of ice, plus 150 mph side wind, and 2.) Gravity acting on the structure plus 1" ice on vertical surfaces plus 30 psf snow on the plan view of the the rotating enclosure. It was determined that the former (survival wind) caused slightly higher stresses in most members.

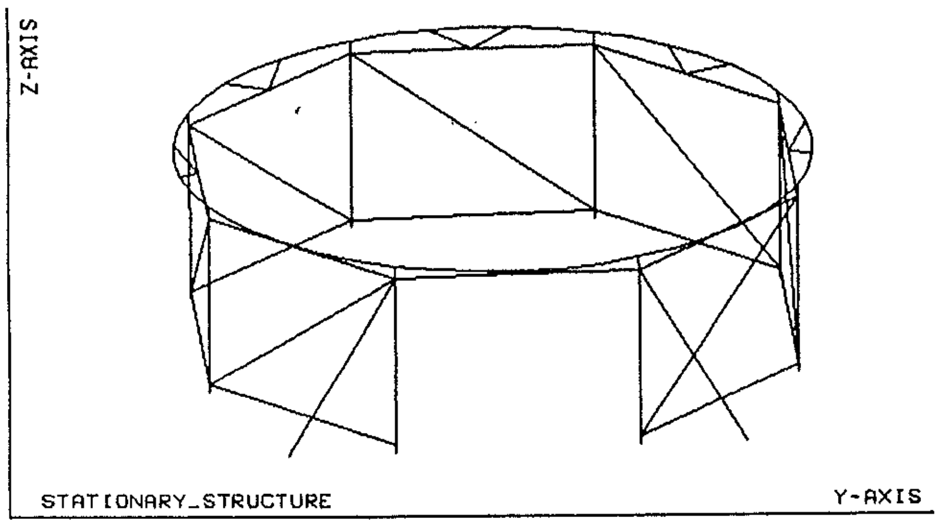
Detailed results are not presented here, but it was concluded that, on average, TS 12 x 12 x 1/4" structural tubing would be adequate for most members, with TS 20 x 12 x 1/4" used for the "arch" members and TS 20 x 12 x 1/2" used for the ring beam. Some optimizing of these members would be anticipated during the detail design.

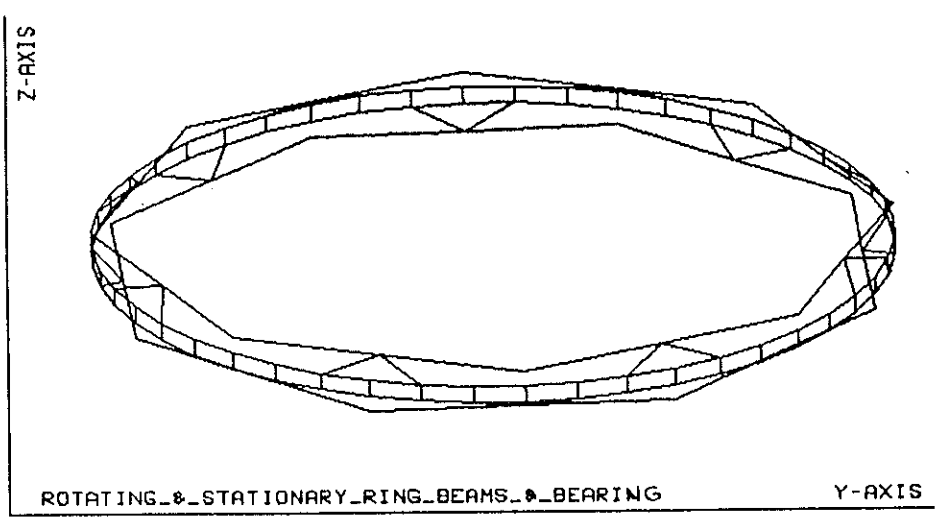
Graphics plots are presented on the following two pages, with various views of the finite element model.



OCTAGONAL ENCLOSURE FINITE ELEMENT MODEL


Z-AXIS
ROTATING_STRUCTURE
Y-AXIS


Z-AXIS
STATIONARY_STRUCTURE
Y-AXIS


Z-AXIS
ROTATING_&_STATIONARY_RING_BEAMS_&_BEARING
Y-AXIS

MAGELLAN PROJECT - DOME ENCLOSURE

INTRODUCTION

The Magellan Project Dome Enclosure concept is shown on drawing E271039. This preliminary structural design is intended as a lightweight approach using conventional hemispherical dome construction techniques. The reasons for making the structure lightweight are: 1.) to (presumably) reduce cost and 2.) to minimize adverse dome seeing effects. The 88′- 6" outside diameter structure has a minimum inside clearance radius from the center of the telescope of 42′ - clearing the telescope by a minimum of 3′- 0".

Although preliminary mechanical design was not performed specifically for the dome enclosure, some of these systems are the same as, or would be very similar to, those for the octagonal enclosure. These areas are discussed below.

The concept employs modular design such that the dome can be virtually fully shop assembled for testing of correctness of engineering and fabrication, and testing of mechanical systems.

STRUCTURAL DESIGN:

The structural design consists of all steel "gore" panels supported at their top ends by one of two arch beams (except that back panels are supported by a "crossbeam") and by a large diameter ring beam at their lower ends.

Each of the 42 gore panels is made as shown in Sec. A-A. The rib along each edge of each gore is a channel, MC10 x 8.4 lbs./ft, rolled to the 44′ outside skin radius. The 3/16" thick steel skin is welded continuously along each edge to the 1/2-rib. Also, horizontal stiffeners made from 3/8" steel plate are welded to the skin and ribs and spaced at approximately 10 ft. intervals up each gore. These serve primarily to hold the rib spacing and angle, and add a little stiffening to the skin.

Actually, most "gores" will be made in two sections (upper and lower) for ease of handling and shipping, making a total of approximately 84 gore panels.

Gore panels are bolted to adjacent panels through the ribs (caulking between ribs), forming eventually a complete "I" shaped rib.

The Ring Beam is fabricated in eight bolted sections and its basic cross section is structural tube, TS 20 x 12 x 1/2" wall.

The Arch Beams are fabricated in TBD bolted sections and are a fabricated box section, outside dimensions 30" x 15" x 1/2" wall.

The crossbeam ("spreader" beam) serves to support the arch beams during construction, support the back gore panels and shutter (closed position) and its cantilevered ends serves as the shutter support in the open position. It is fabricated from 1/2" steel plate.

SHUTTERS

Although no actual preliminary design was done on the shutters for the dome enclosure, it is anticipated that that they will be somewhat similar to the bi-parting shutters for the (previously discussed) octagonal enclosure. That is, there will be a relatively heavy fabricated curved member along each edge which will give the shutters bending stiffness and strength and provide for sealing when the shutters are closed.

The shutters will also be skinned with 3/16" thick steel, and will have ribs and stiffeners as required.

One major variation from the octagonal enclosure shutter is that here numerous bolted joints will be necessary, to allow for shop assembly and testing and subsequent shipping. For this reason, it was anticipated that the shutters would weigh about 30% more than in the octagonal enclosure design.

WINDSCREEN

Although no actual preliminary design was made for a windscreen specifically for the dome enclosure, the concept would be the same as for the octagonal enclosure (ref "Windscreen", Octagonal Enclosure section of this report).

That is, there is also insufficient space to place a draped, rolled, or bellows type windscreen in this system, so a side-ways telescoping unit stored along the inside surface of the bi-parting shutters is anticipated. Of course, the unit would have to have the same radius of curvature as the shutter, and could possibly be made (also) from aluminum honeycomb sandwich panels. Reference drawing E271040 (Octagonal Enclosure Windscreen).

DOME ROTATION BEARING/TRUCK ALTERNATIVE

The dome rotation bearing for this system can be identical to that of the Octagonal Enclosure (ref Octagonal Enclosure section of this report). That is, either the ball bearing type or truck type would be suitable, just as in the Octagonal Enclosure, especially since the same ring beam structural section has been used in both designs. All earlier pertinent descriptions and discussions are therefore valid also for the Dome Enclosure, and are not reiterated here.

DOME ROTATION DRIVE

The dome rotation drive comments from the earlier Octagonal Enclosure discussion, aré likewise applicable in the case of the Dome Enclosure.

MAGELLAN PROJECT DOME ENCLOSURE

FINITE ELEMENT ANALYSIS

A concept design level, finite element type, structural analysis was performed to help size the structural members in this monocoque structure. Of particular interest was the steel skin thickness and its shear stability.

The modelling progressed from very simple models (without ribs and with arches only in the area of the slit) to a rather complex version including ribs, rib offsets to the steel skin, and arch beams all the way down the back side to the ring beam. This final version required 1,111 nodes, 1,190 beam elements, 576 thin plate/shell elements, and 6,569 equations with a bandwidth of 372. The large size of this model (unusual for a preliminary design model) was necessary due to the large number of gores in the structure, which was in turn determined by the standard 72" maximum steel sheet width available commercially.

Graphics plots are included on the following three pages, consisting of: 1. Front quartering and Rear quartering views of the entire finite element model; 2.) Front and rear quartering views of plate elements only in the rotating dome, and 3.) A view of the beam elements in both the rotating and stationary portions of the enclosure.

Stresses in beams and plates were evaluated for three different load conditions: 1.) Gravity acting on the structure plus 1" of ice over the entire system, plus 150 mph side wind. 2.) Gravity acting on the structure plus ice on the vertical surfaces plus 30 psf snow on the plan view of the dome. And 3.) Gravity acting on the structure with a 0.3 "g" earthquake applied as a static load sideways on the system (perpendicular to the length of the slit).

Although detailed results are not being presented herein, some notable results should be mentioned:

1. The total stress in the arch beams under any of the above load conditions and structural configurations (that is, with and without ribs, with and without running all the way down to the ring beam on the back side) was very low; about 25% of their allowable stress by A.I.S.C. requirements. (The arch beams were sized by a rough manufacturability criterion).

2.) The total stress in the ribs was about 40% of their allowable stress by A.I.S.C. requirements. The MC10 x 8.4 ribs were chosen for their light weight and ability to withstand reasonable punishment during handling and installation.

3.) The total stress in the ring beams was about 50% of their allowable stress by A.I.S.C. requirements. This, however, does assume (as in the case of the Octagonal Enclosure preliminary design) that radial support exists from the stationary building below.

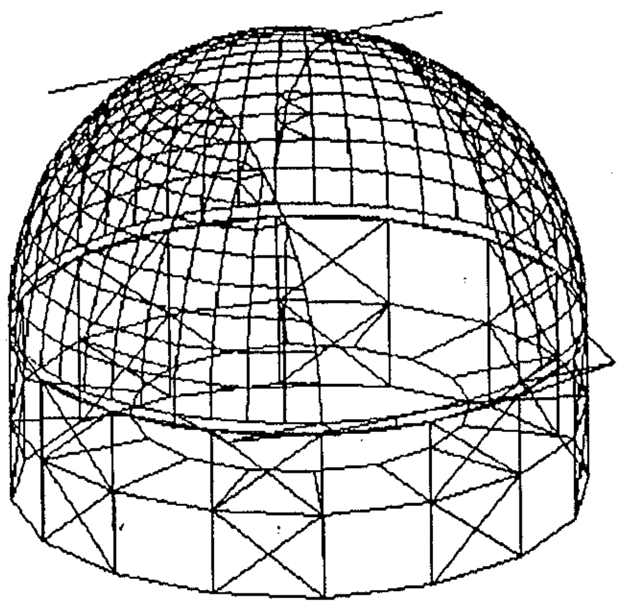
4.) The maximum shear stress in the skin is the critical design criterion, due to its shear stability. Although the stresses in the beams (arches, ring beams) were low even without ribs and without full-span arches, adding ribs and lengthening the arches caused the skin stress to lower considerably. The maximum shear stress anywhere in the dome was highest under the snow load case, and in the final structural configuration (summarized in this report) this stress was 1,770 psi.

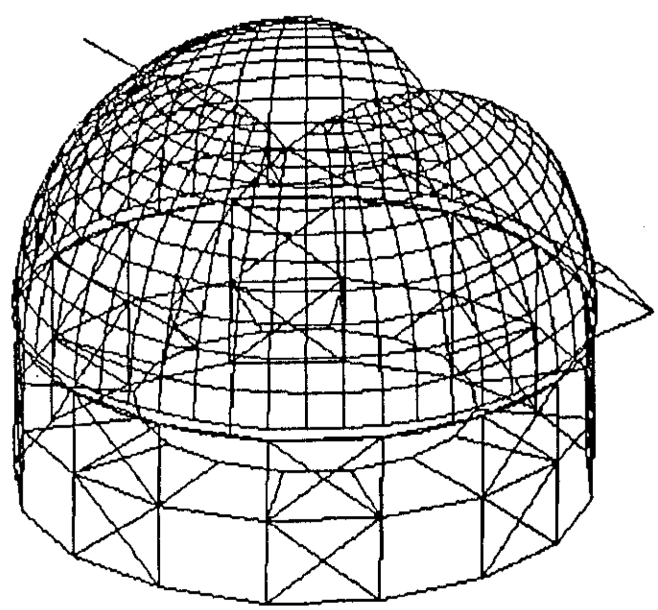
SKIN SHEAR BUCKLING STRESS:

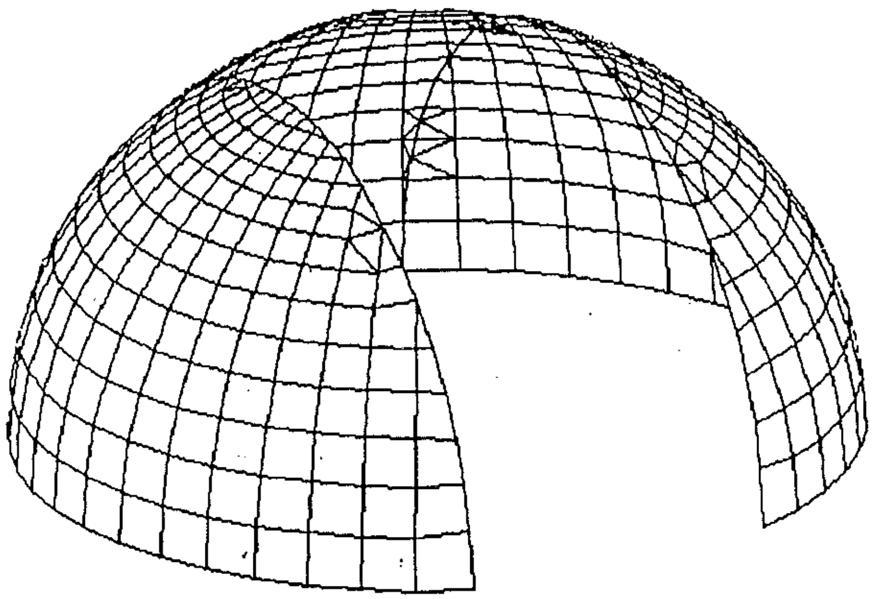
The critical failure mode for the dome skin is shear buckling; that is, its tendency under high load to buckle out of the way thus redistributing load throughout the structure. It is thought that this could cause an extreme increase in the stresses in the ribs, arches and ring beams, leading to loss of the shutter/arch seal and eventually the possibility of catastrophic failure of the dome structure.

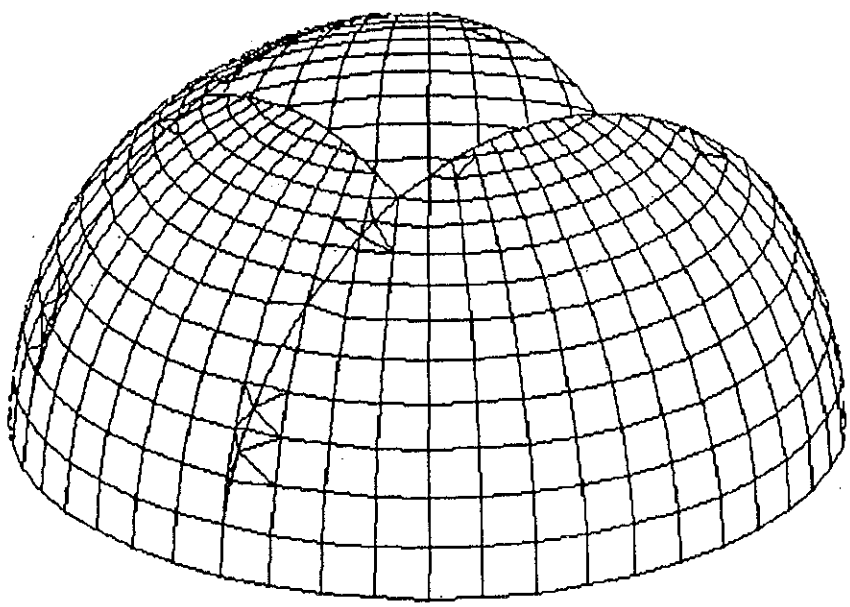
A thin shear panel which is large (that is, large distances between side and end stiffeners as compared to the skin thickness) will buckle at a much lower stress than it can carry before fracturing in shear. Conversely, a curved shear panel is much less likely to buckle than a flat one. Although it is believed that some useful test data on curved shear panels exists, considerable investigation of this subject would be required to determine very accurately the shear buckling stress for these gore panel skins.

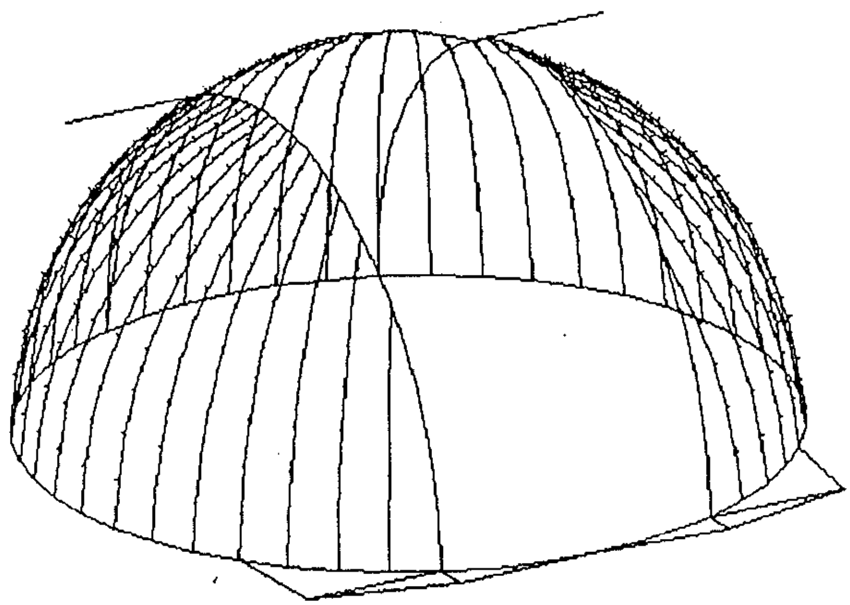
Therefore, a simple formula (Roark, "Formulas for Stress and Strain", 4th edition) was used for this preliminary design. There is some question of interpretation of this formula; under one interpretation the actual maximum stress of 1,770 psi would be just acceptable; under the other interpretation the skin would have to be thicker (1/4") in some areas of the dome. It is felt that the analysis is sufficiently conservative, however, that the 3/16" thick skin, on average can be used for this preliminary design.

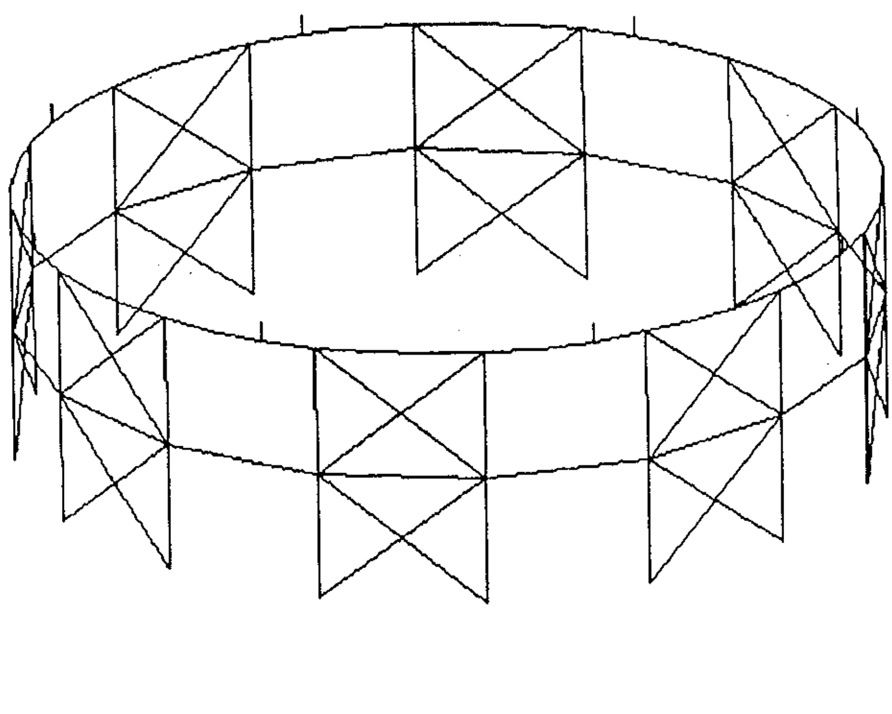












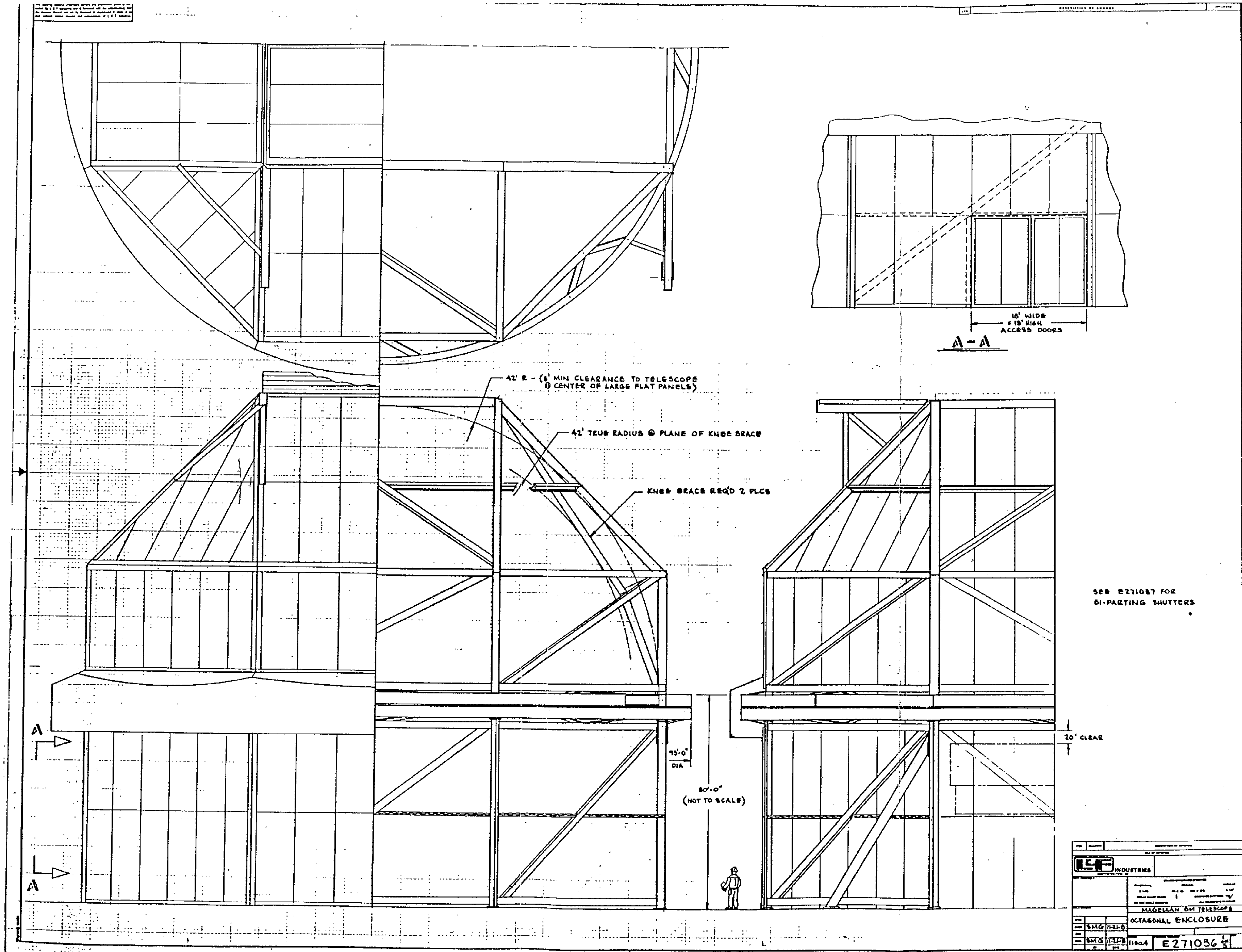
DOME ENCLOSURE FEA WEIGHT SUMMARY

ITEM/DESCRIPTION	WEIGHT
Ring Beam - TS 20 x 12 x 1/2"	28,600
Arches (only to back spreader) - 30 x 15 x 1/2"	24,000
Arches (back spreader to ring beam - ditto	13,800
Back Spreader + Shutter Support 30 x 15 x 1/2"	11,000
Lower Shutter Supports - TS 20 x 12 x 1/2"	9,000
Ribs - (2) MC10 x 8.4	32,600
Skin - @ 3/16"	73,000
Shutters (2)	70,000
Misc. Structural (horizontals, stiffeners, etc.)	10,000
Misc. Mech. (drives, skirt, windscreen, etc.)	15,000
TOTAL WEIGHT ROTATING DOME	287,000 lbs.

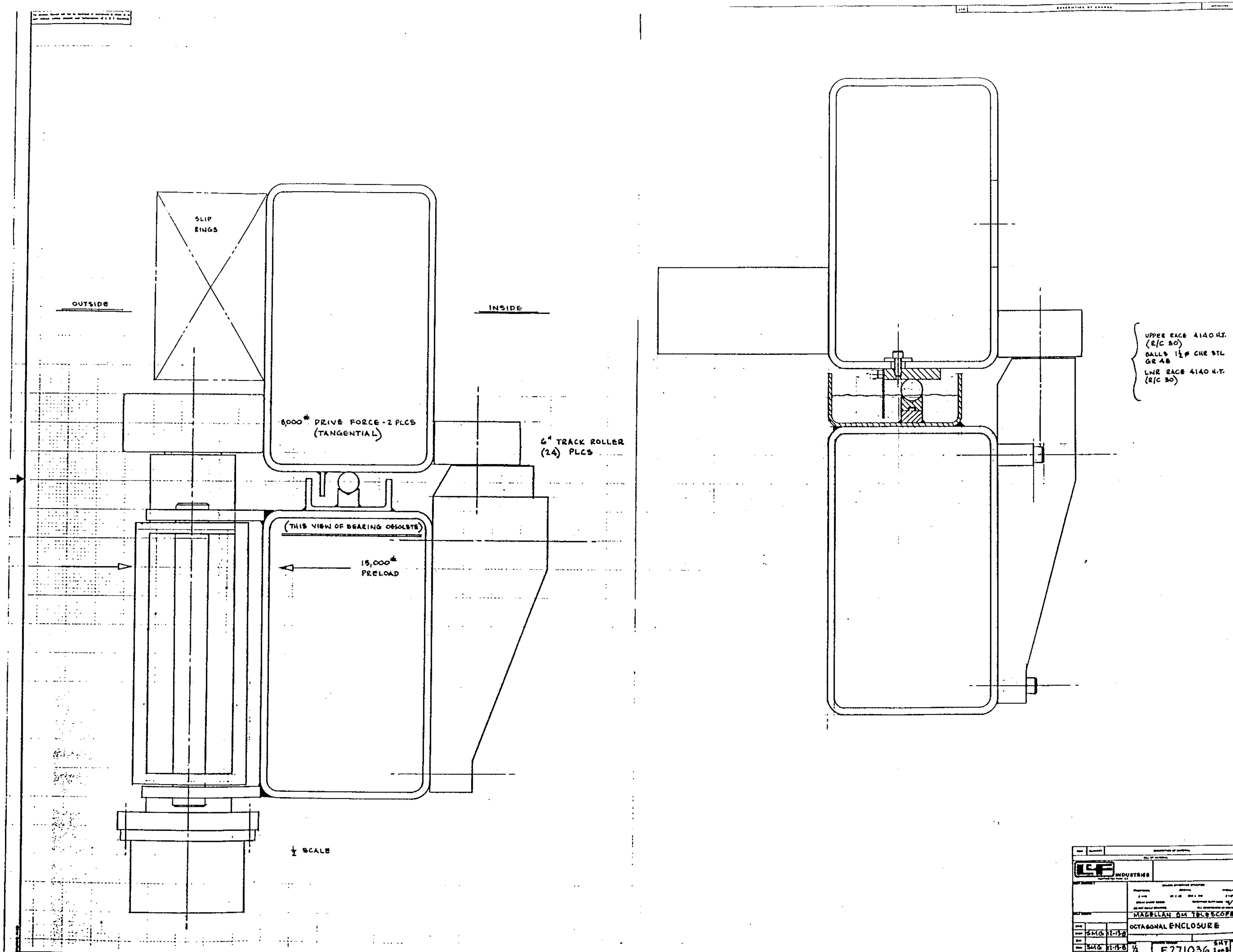
Not included: Double skin if required; insulation.

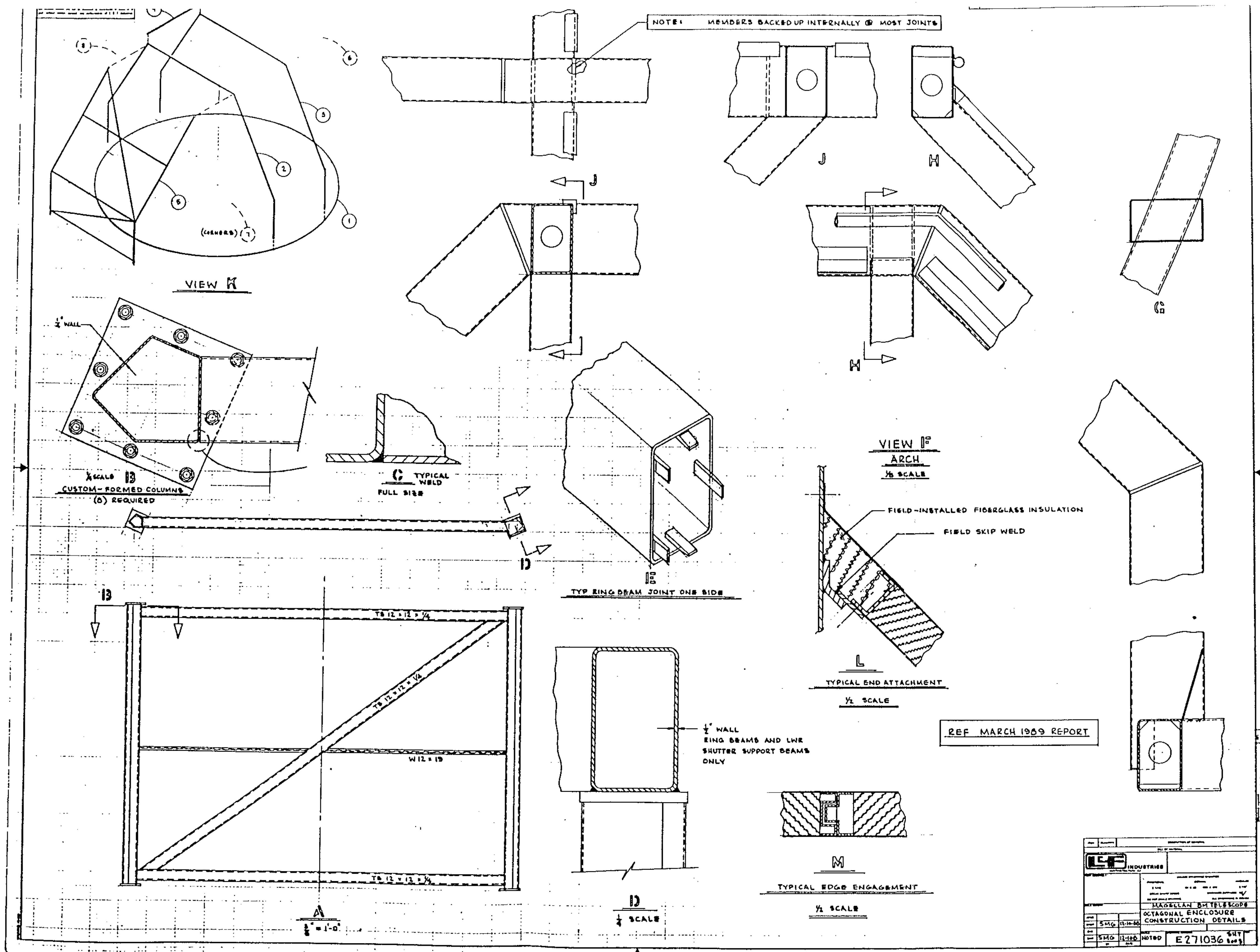
NOTE: 3/16" thick skin is best estimate at this time. However, some possibility exists that 1/4" thick may be required, or that even a 1/8" thick skin might be adequate. (Pending more detailed investigation of shear stability of skin).

APPENDIX

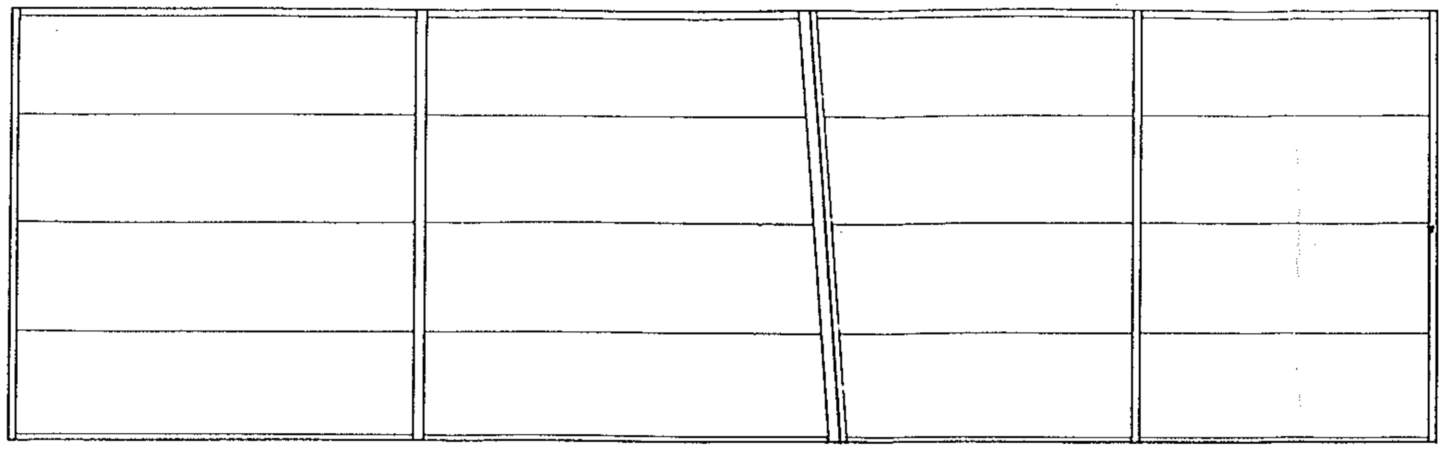


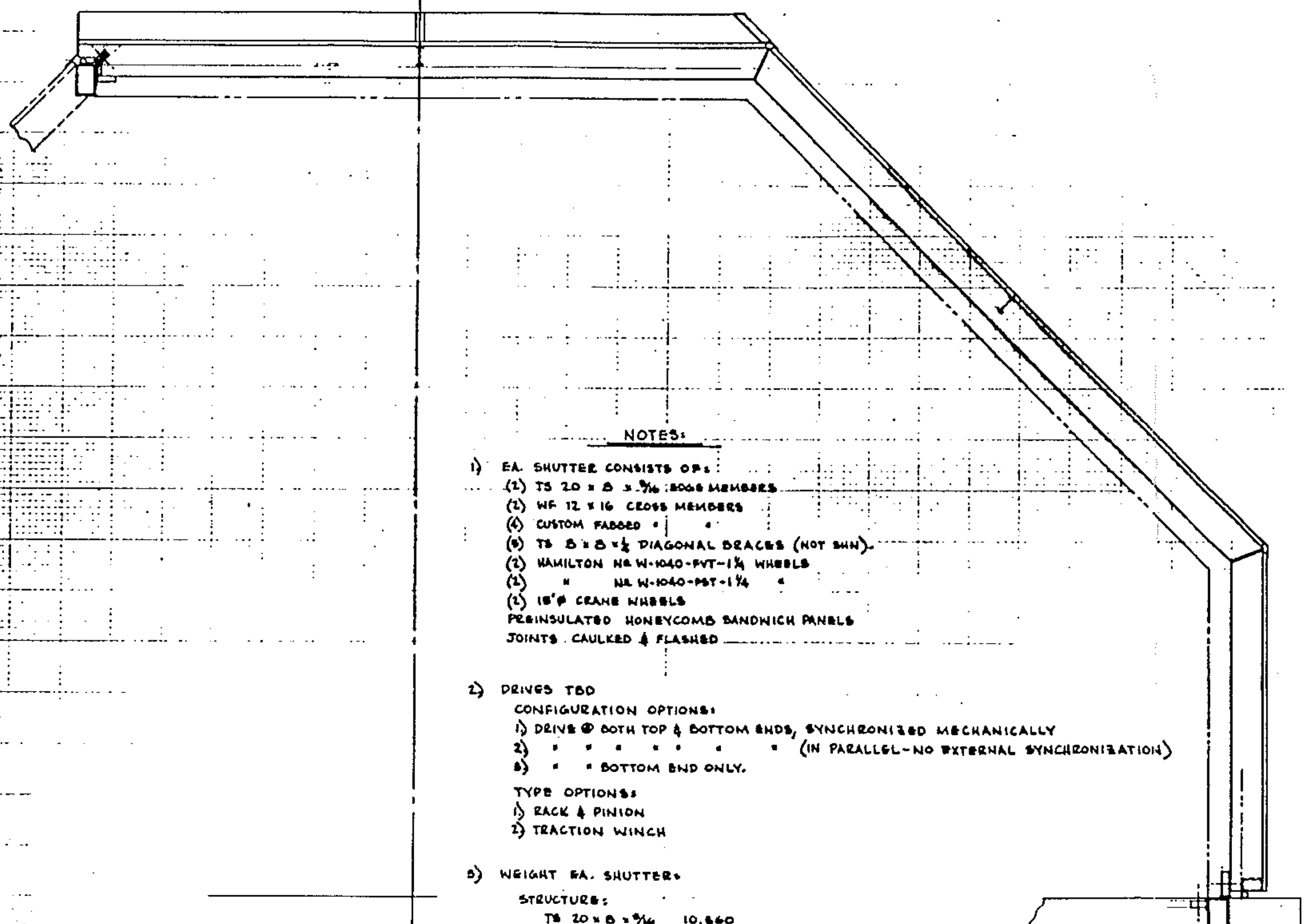
18' WIDE
x 18' HIGH
ACCESS DOORS
A-A
42' R - (3' MIN CLEARANCE TO TELESCOPE
@ CENTER OF LARGE FLAT PANELS)
42' TRUE RADIUS @ PLANE OF KNEE BRACE
KNEE BRACE REQ'D 2 PLCS
SEE E271037 FOR
BI-PARTING SHUTTERS
A
A
95'-0"
DIA
80'-0"
(NOT TO SCALE)
20' CLEAR
E271036
INDUSTRIES
MAGELLAN 8M TELESCOPE
OCTAGONAL ENCLOSURE
SMG
SMG
E271036

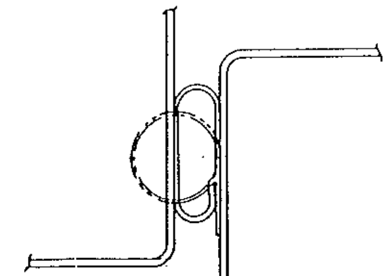

SLIP RINGS
OUTSIDE
INSIDE
8,000# DRIVE FORCE - 2 PLCS (TANGENTIAL)
6" TRACK ROLLER (24) PLCS
(THIS VIEW OF BEARING OBSOLETE)
15,000# PRELOAD
1/2 SCALE
UPPER RACE 4140 H.T. (R/C 50)
BALLS 1 1/2 ⌀ CHR STL GR 48
LWR RACE 4140 H.T. (R/C 50)
L&F INDUSTRIES
MAGELLAN 8M TELESCOPE
OCTAGONAL ENCLOSURE
SMG 12-13-8
SMG 12-13-8
1/2
E271036
SHT 2 OF 3
E271036

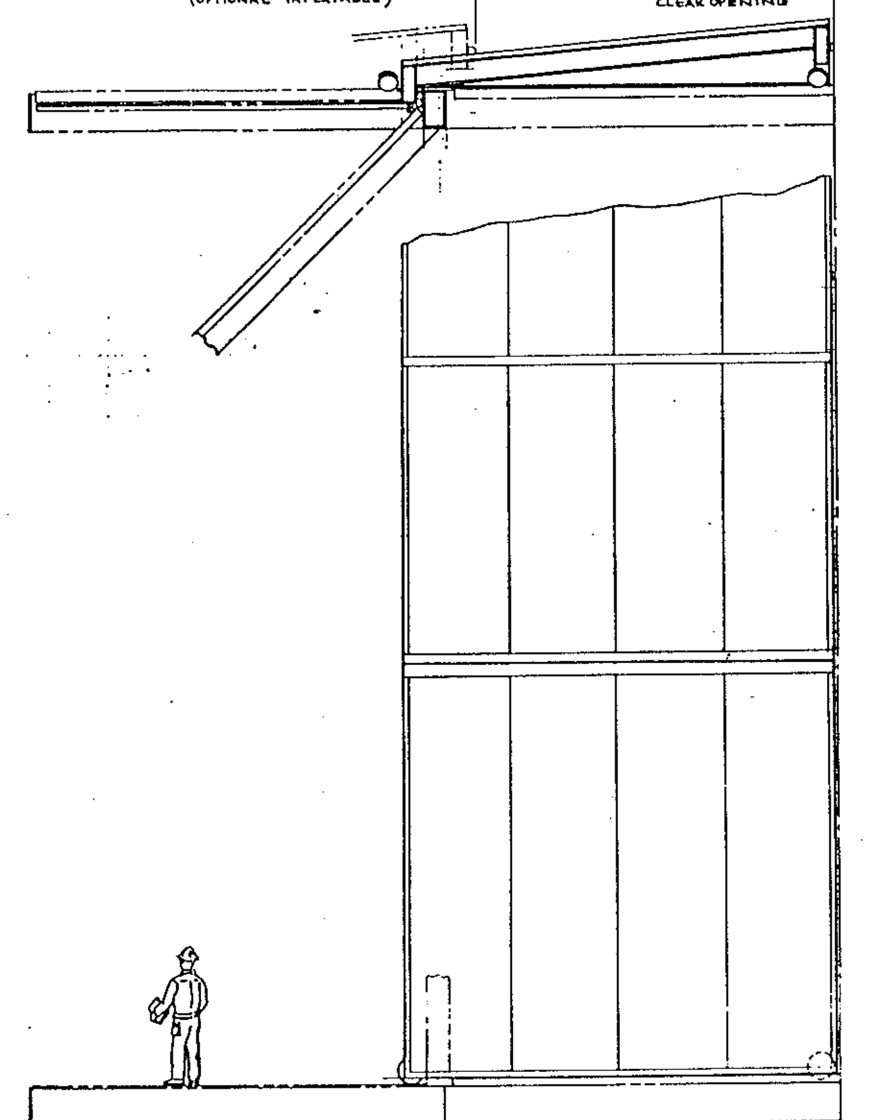


NOTE: MEMBERS BACKED UP INTERNALLY @ MOST JOINTS
J
H
G
VIEW K
1/4" WALL
CUSTOM-FORMED COLUMNS
(8) REQUIRED
B
C TYPICAL WELD
FULL SIZE
D
TYP RING BEAM JOINT ONE SIDE
VIEW F
ARCH
1/8 SCALE
FIELD-INSTALLED FIBERGLASS INSULATION
FIELD SKIP WELD
L
TYPICAL END ATTACHMENT
1/2 SCALE
REF MARCH 1989 REPORT
TS 12 x 12 x 1/4
W12 x 19
A
1/8" = 1'-0"
1/4" WALL
RING BEAMS AND LWR
SHUTTER SUPPORT BEAMS
ONLY
D
1/4 SCALE
M
TYPICAL EDGE ENGAGEMENT
1/2 SCALE
INDUSTRIES
MAGELLAN 8M TELESCOPE
OCTAGONAL ENCLOSURE
CONSTRUCTION DETAILS
SMG
NOTED
E271036









NOTES:

1) EA. SHUTTER CONSISTS OF:
   (2) TS 20 x 8 x 5/16 EDGE MEMBERS
   (2) WF 12 x 16 CROSS MEMBERS
   (4) CUSTOM FABBED " "
   (8) TS 8 x 8 x 1/4 DIAGONAL BRACES (NOT SHN).
   (2) HAMILTON NO W-1040-FVT-1 1/4 WHEELS
   (2) " NO W-1040-PST-1 1/4 "
   (2) 18"ø CRANE WHEELS
   PREINSULATED HONEYCOMB SANDWICH PANELS
   JOINTS CAULKED & FLASHED

2) DRIVES TBD
   CONFIGURATION OPTIONS:
   1) DRIVE @ BOTH TOP & BOTTOM ENDS, SYNCHRONIZED MECHANICALLY
   2) " " " " " " " (IN PARALLEL-NO EXTERNAL SYNCHRONIZATION)
   3) " " BOTTOM END ONLY.
   TYPE OPTIONS:
   1) RACK & PINION
   2) TRACTION WINCH

3) WEIGHT EA. SHUTTER:

STRUCTURE:		
TS 20 x 8 x 5/16	10,860	
TS 8 x 8 x 1/4	3,300	
W 12 x 16	1,780	
TOTAL STRUCTURE	15,890	15,890#
PREINSULATED PANELS		7,800#
MECHANICAL, MISC		2,000#
TOTAL EA SHUTTER –		25,700#

(DOESN'T INCLUDE ADD'L STRUCTURE REQ'D IN ENCLOSURE TO SUPPORT SHUTTERS)

L&F INDUSTRIES

25,700# EA.

MAGELLAN 8M TELESCOPE

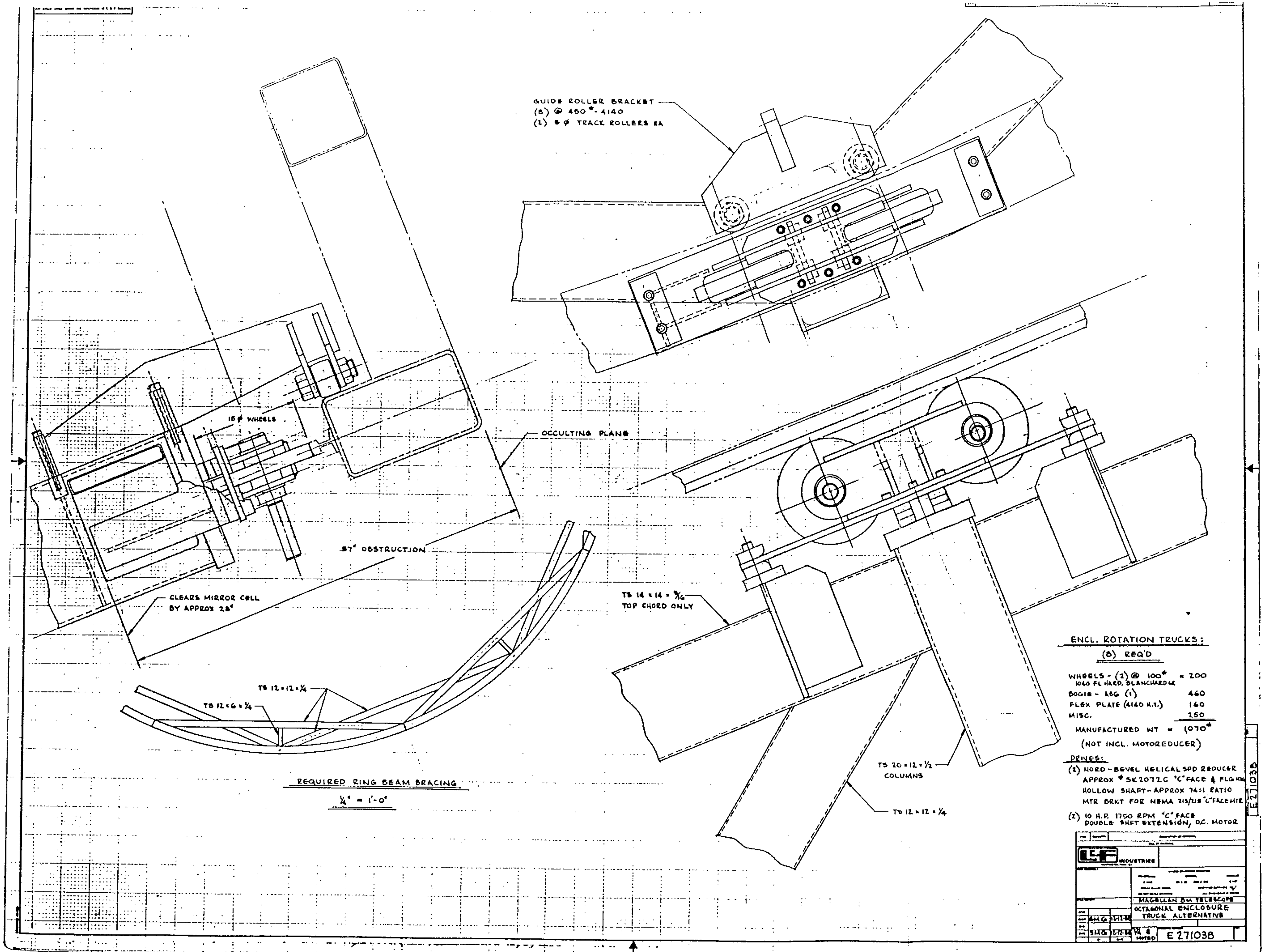
BI-PARTING SHUTTERS

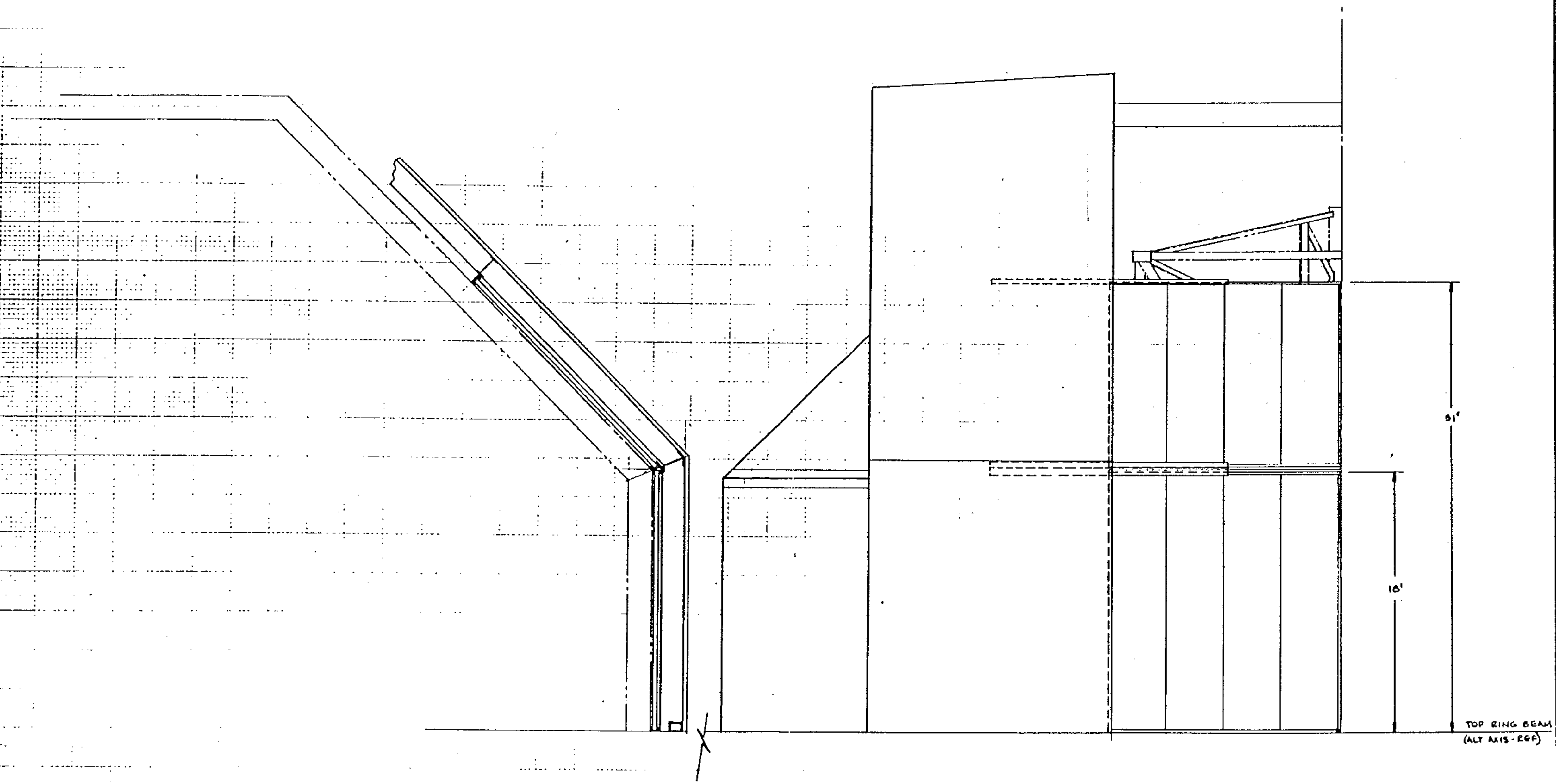
SMG 11-29-?

SMG 11-29-?

1/8"=1' (1:32)

E271037


GUIDE ROLLER BRACKET
(8) @ 480#-4140
(2) 8 ø TRACK ROLLERS EA
15 ø WHEELS
OCCULTING PLANE
57" OBSTRUCTION
CLEARS MIRROR CELL
BY APPROX 28"
TS 14 x 14 x 5/16
TOP CHORD ONLY
TS 12 x 12 x 1/4
TS 12 x 6 x 1/4
REQUIRED RING BEAM BRACING
1/4" = 1'-0"
TS 20 x 12 x 1/2
COLUMNS
TS 12 x 12 x 1/4
ENCL. ROTATION TRUCKS:
(8) REQ'D
WHEELS - (2) @ 100# = 200
1040 FL HARD, BLANCHARD GR
BOGIE - A36 (1) 460
FLEX PLATE (4140 H.T.) 160
MISC. 250
MANUFACTURED WT = 1070#
(NOT INCL. MOTOREDUCER)
DRIVES:
(2) NORD - BEVEL HELICAL SPD REDUCER
APPROX #SK2072C "C" FACE & FLG MTG
HOLLOW SHAFT - APPROX 74:1 RATIO
MTR BRKT FOR NEMA 215/218 "C" FACE MTR
(2) 10 H.P. 1750 RPM "C" FACE
DOUBLE SHFT EXTENSION, D.C. MOTOR
L-F INDUSTRIES
MAGELLAN 8M TELESCOPE
OCTAGONAL ENCLOSURE
TRUCK ALTERNATIVE
SMG
1/4 & NOTED
E 271038



INDUSTRIES

MAGELLAN PROJECT 8M

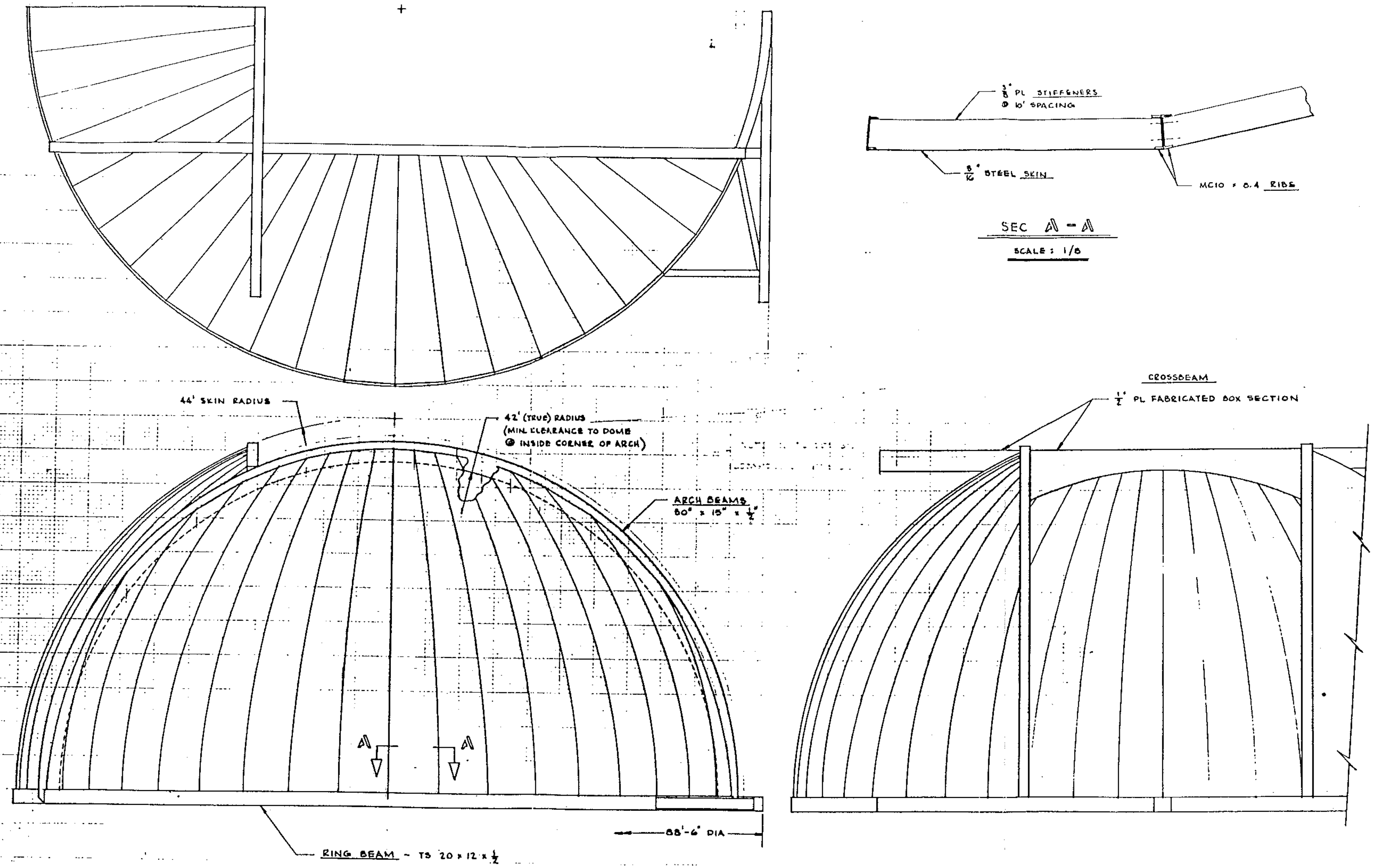
-WINDSCREEN-

OCTAGONAL ENCLOSURE

SMG	5-18-9	
SMG	1-18-9	

$3/16" = 1'$

E271040



LSF INDUSTRIES

SEPARATE SUMMARY

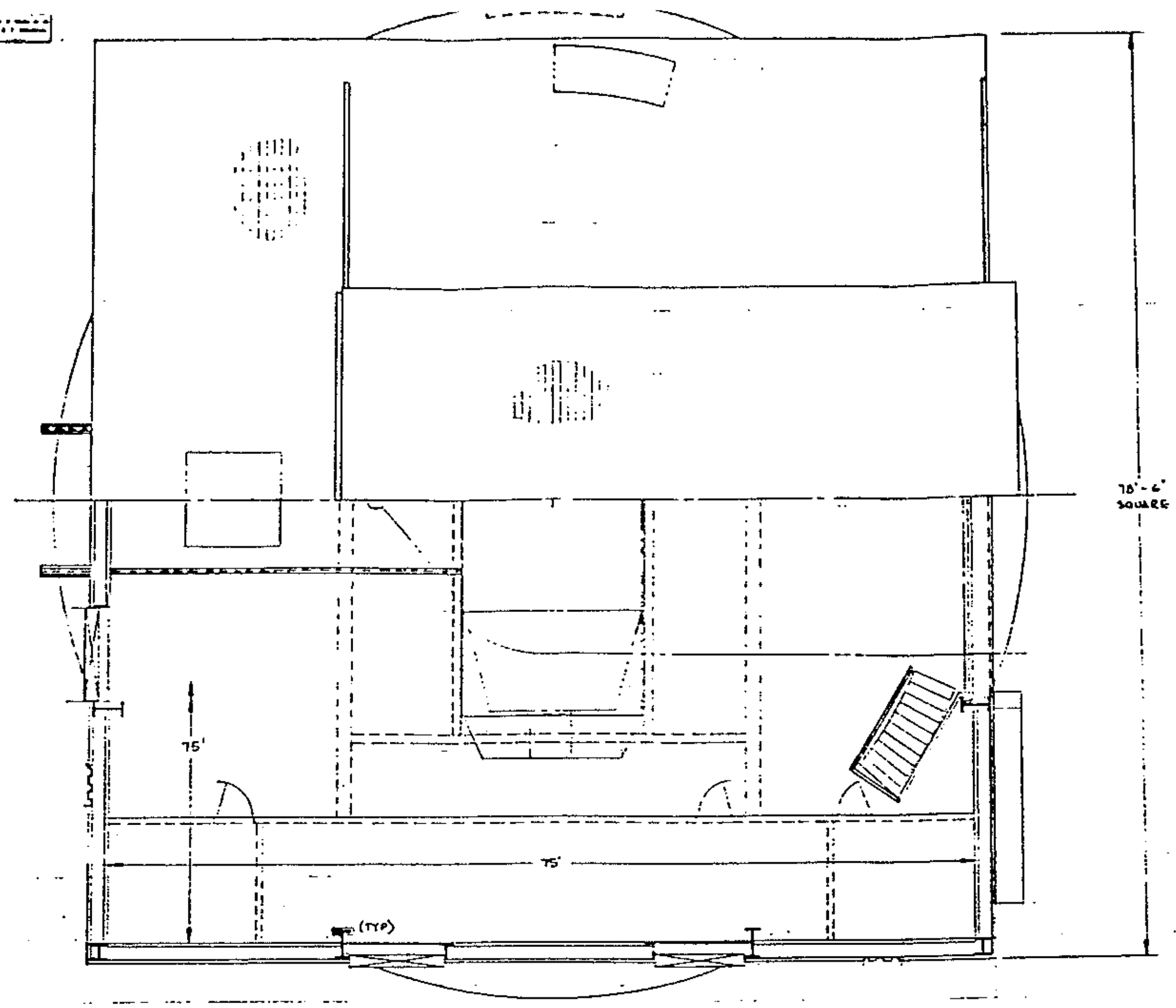
MAGELLAN 8M TELESCOPE

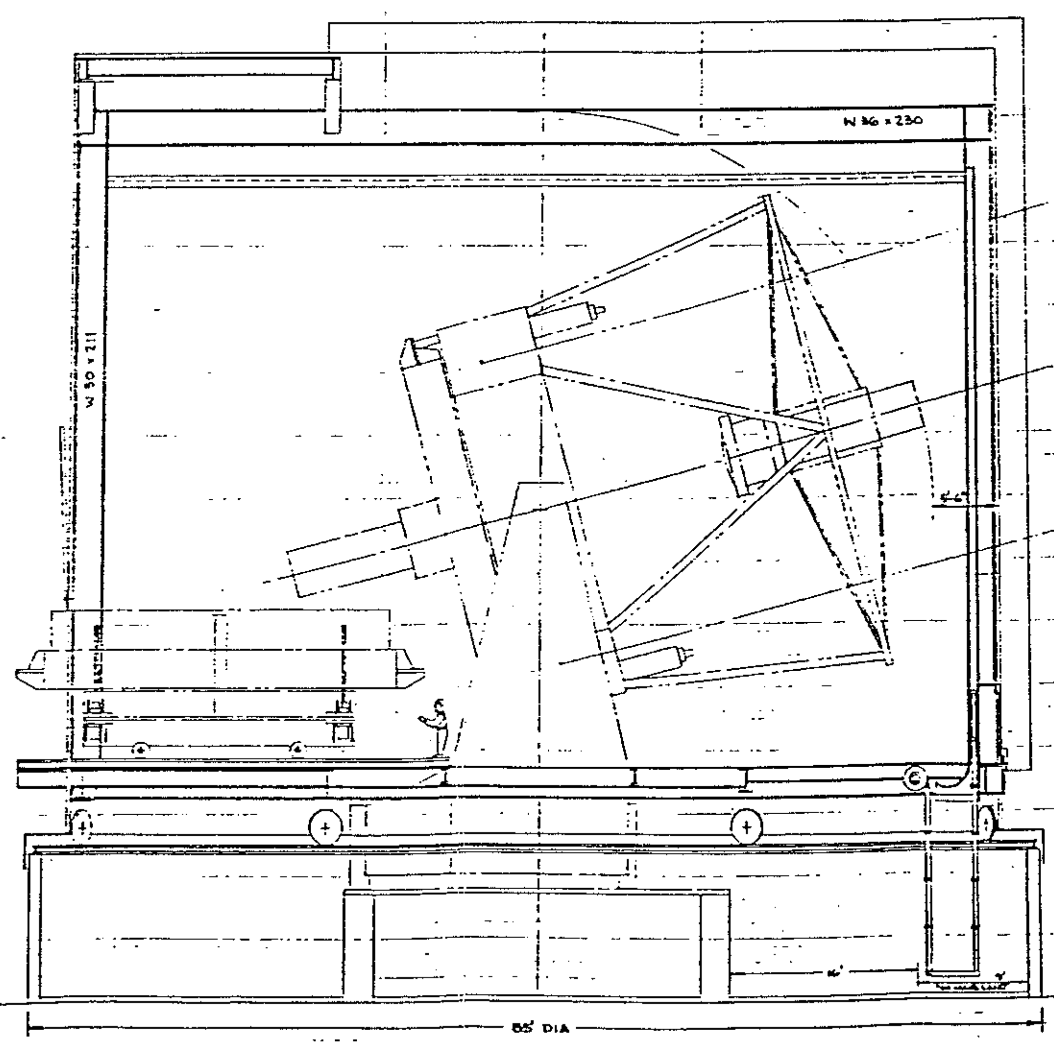
DOME ENCLOSURE

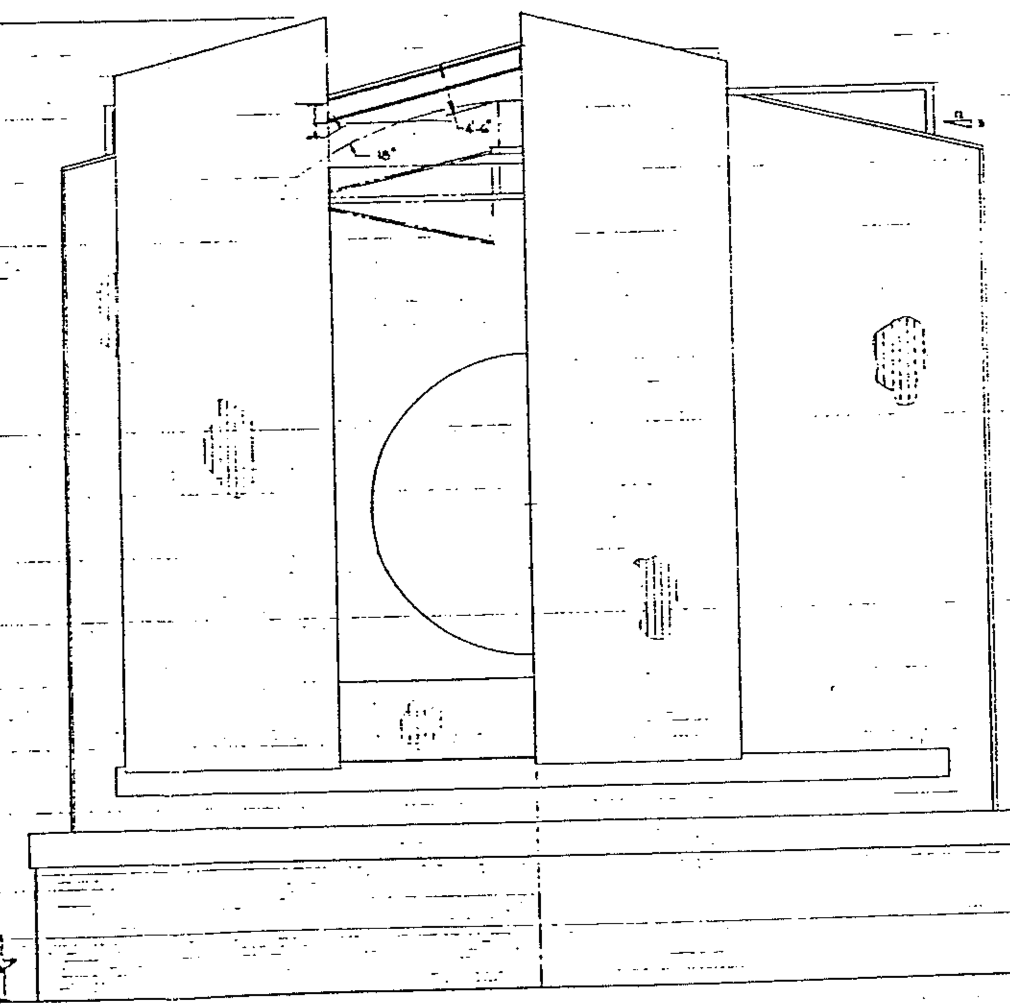
	SMG	1-20-89
	SMG	1-20-9

1/4"=1'-0"

E271039







INDUSTRIES

GIN 8M TELESCOPE

75' ENCLOSURE

SMG 1-4-7

SMG 1-4-7

E 271100 SHT 1 OF 4